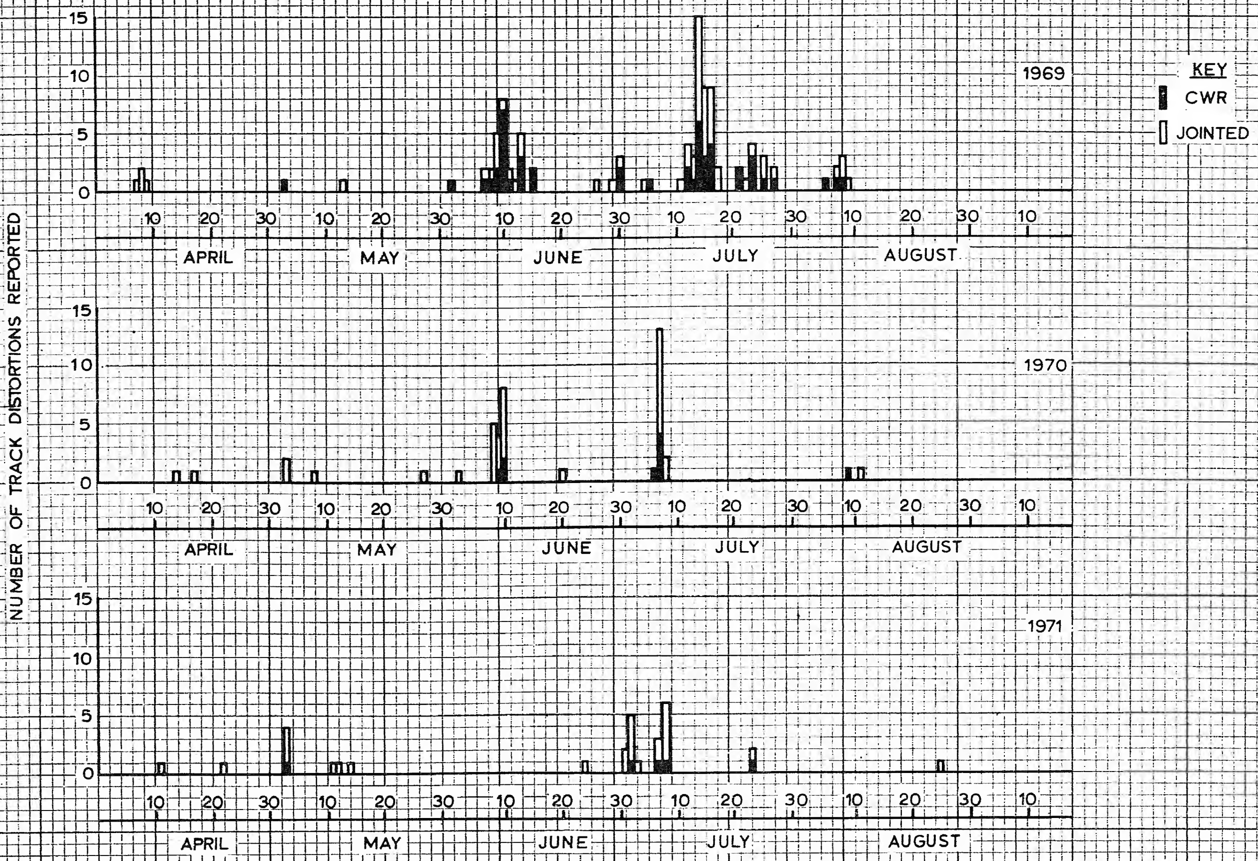
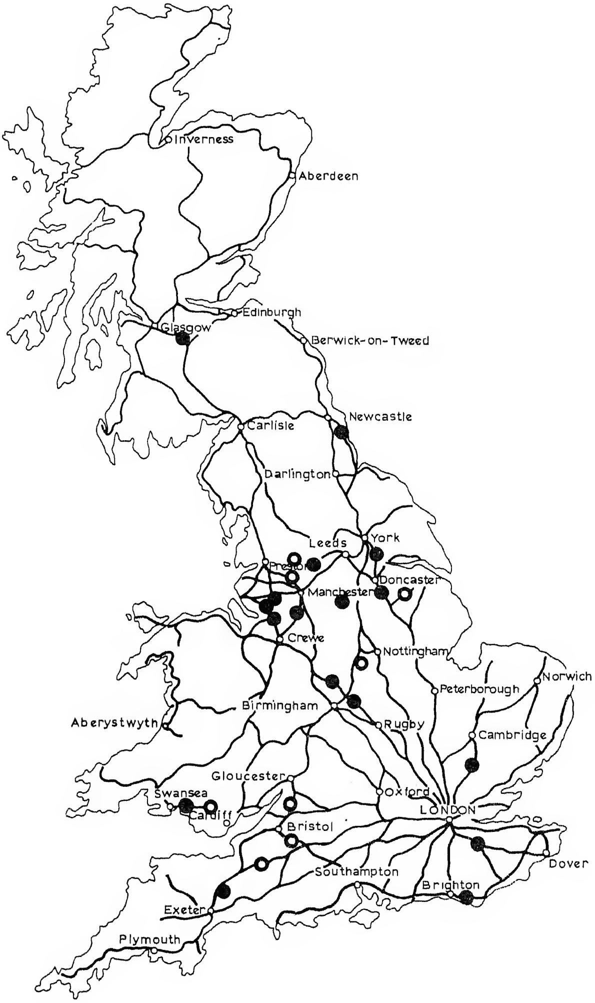
ANNEXURE A

DISTRIBUTION BY DATE OF TRACK DISTORTIONS ON B.R.— 1969, 1970 & 1971



ANNEXURE B

TRACK DISTORTIONS 7–15 JUNE 1969

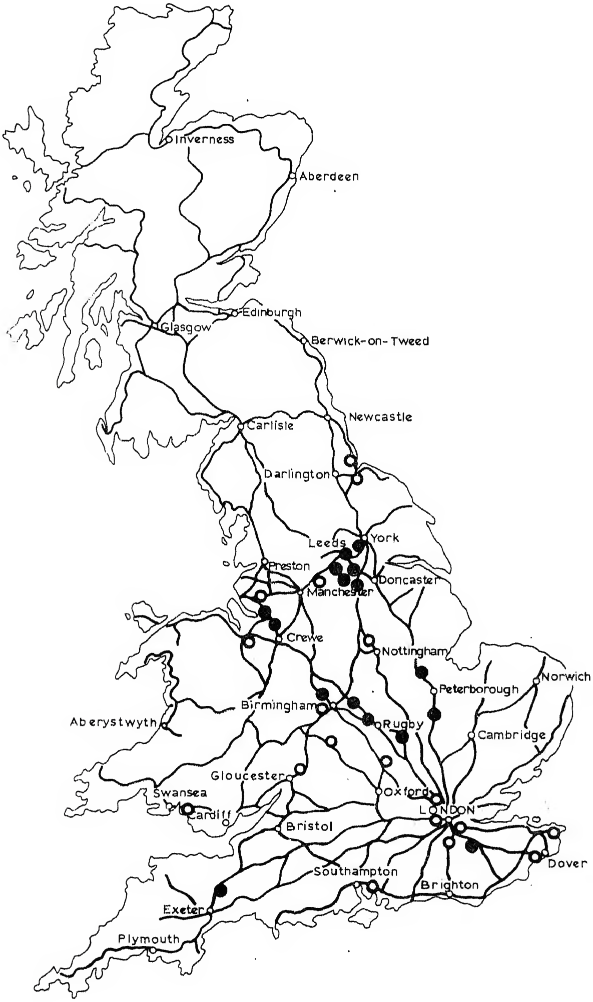


● Distortions CWR Track

○ Distortions Jointed Track

ANNEXURE C

TRACK DISTORTIONS 12–16 JULY 1969

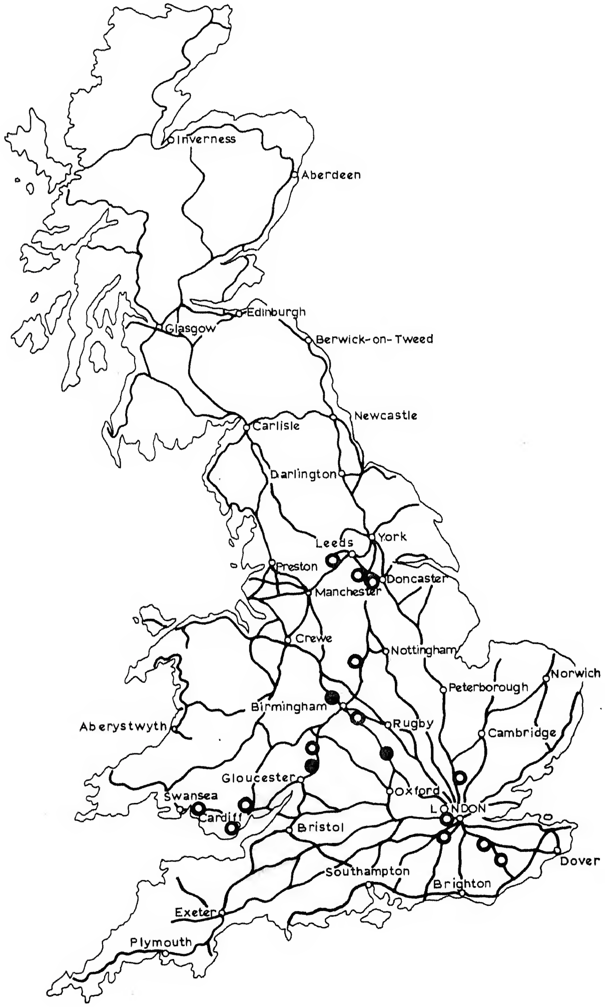


● Distortions CWR Track

○ Distortions Jointed Track

ANNEXURE D

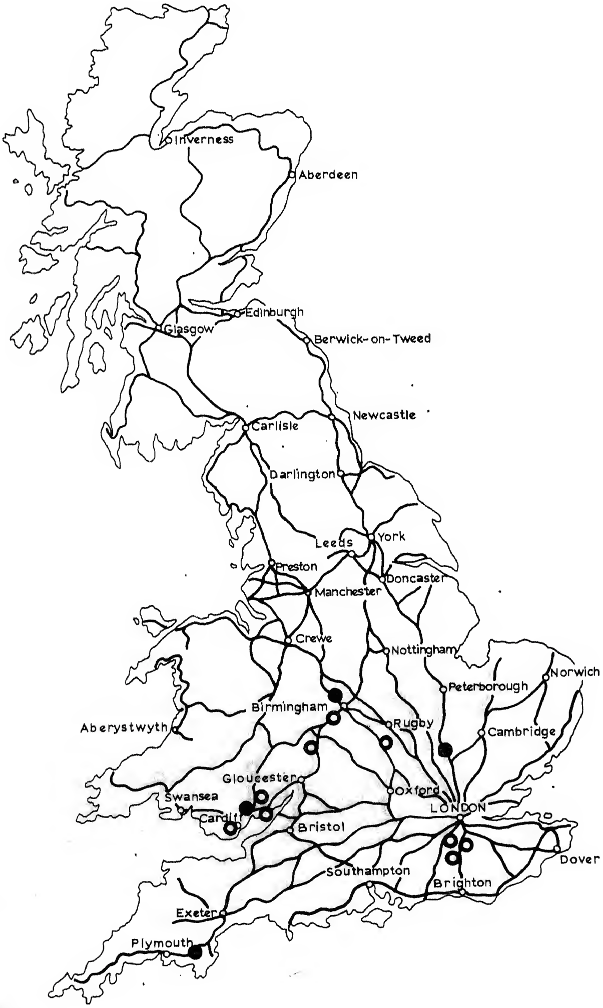
TRACK DISTORTIONS 8–10 JUNE 1970



● Distortions CWR Track

○ Distortions Jointed Track

TRACK DISTORTIONS 7 JULY 1970

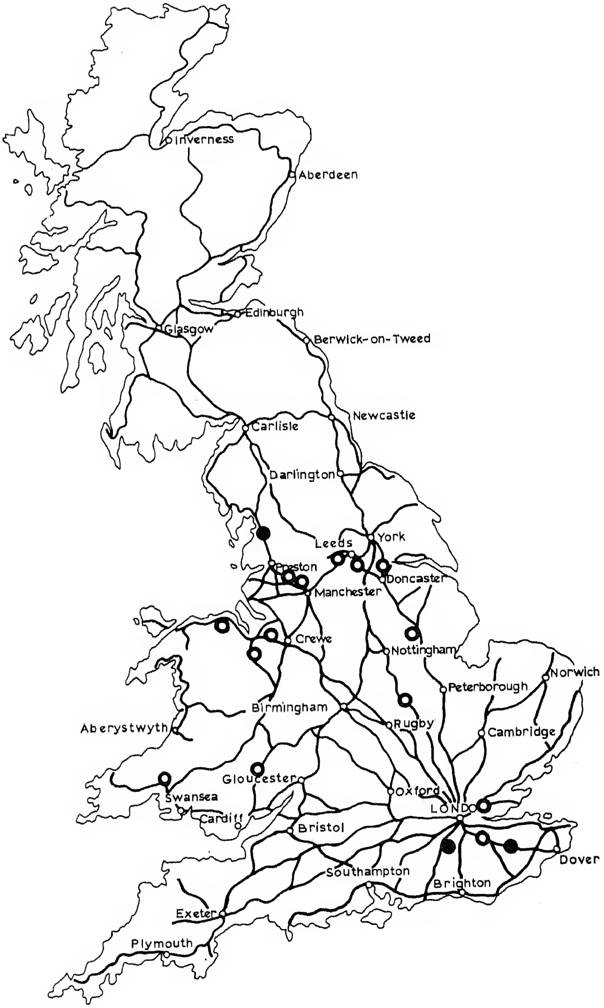


● Distortions CWR Track

○ Distortions Jointed Track

ANNEXURE F

TRACK DISTORTIONS 1—8 JULY 1971



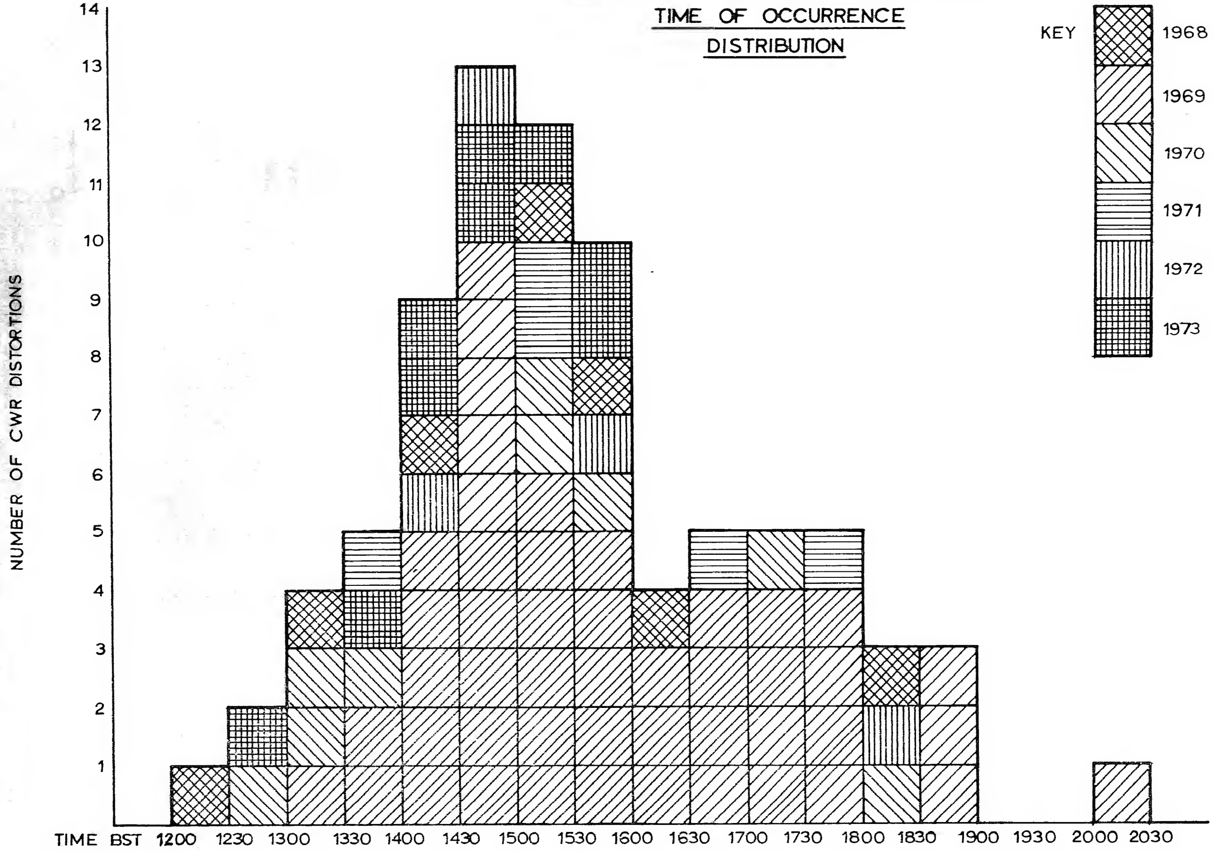
● Distortions CWR Track

○ Distortions Jointed Track

ANNEXURE G

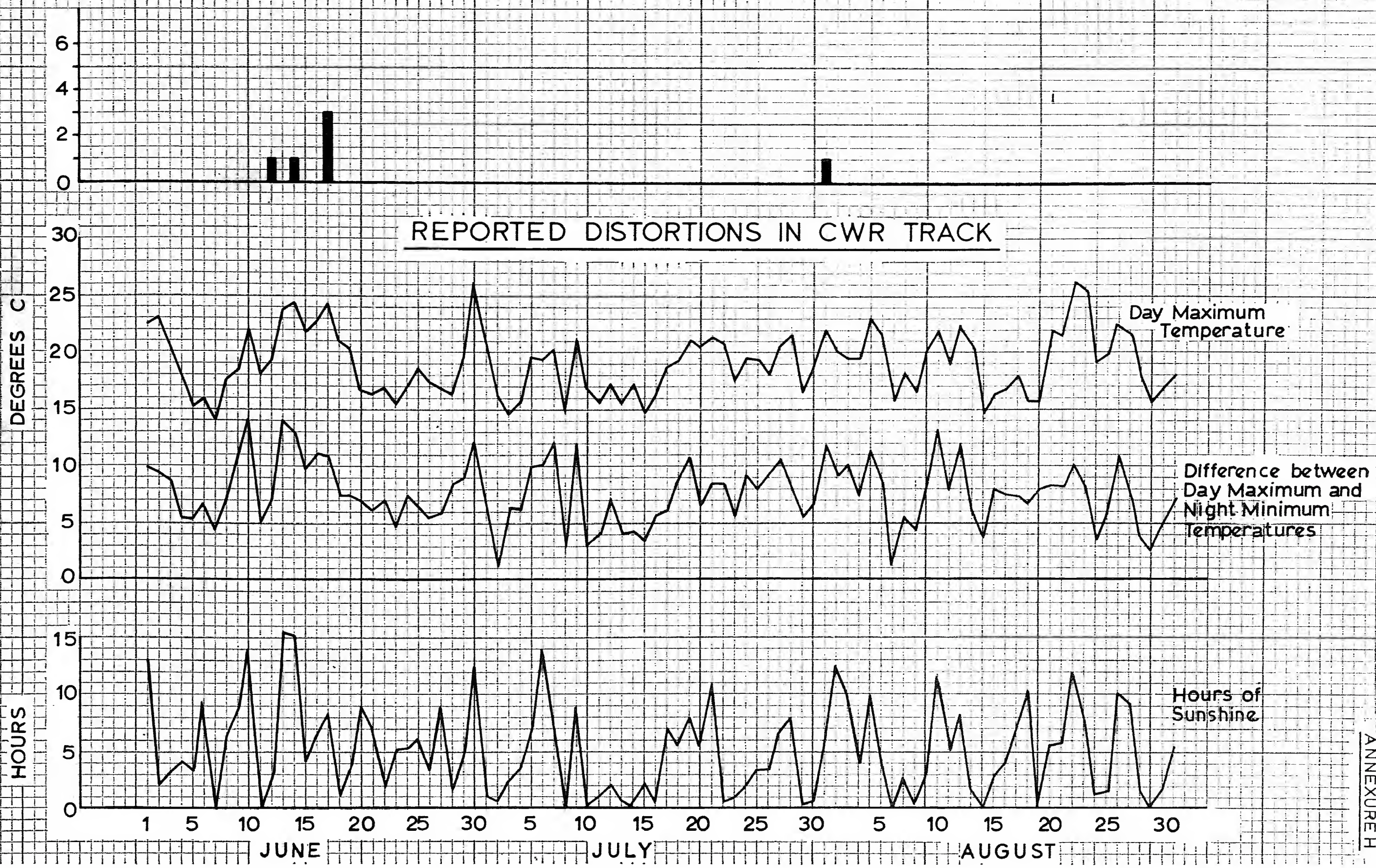
CWR DISTORTIONS 1968-1973

TIME OF OCCURRENCE DISTRIBUTION



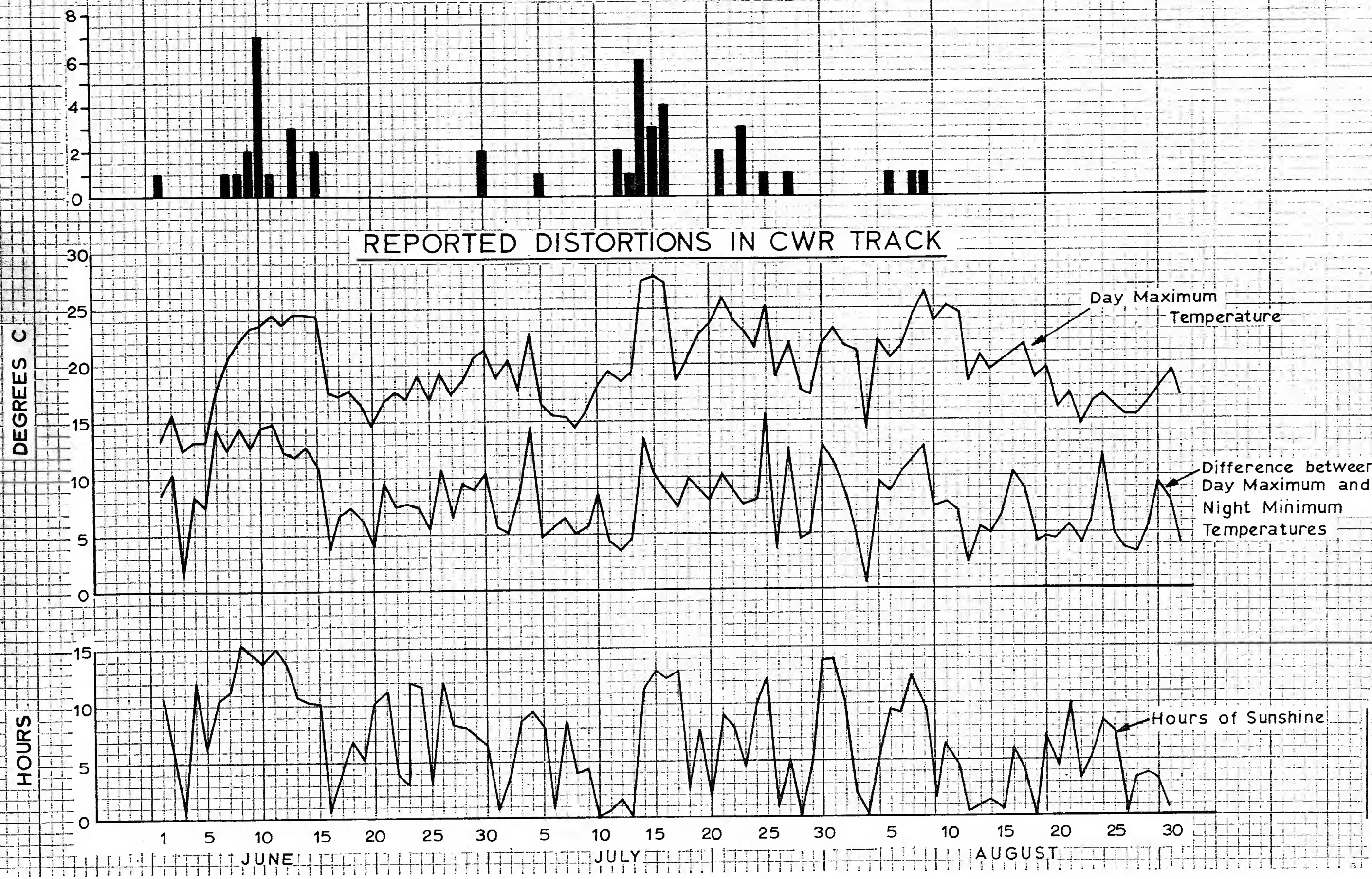
ANNEXURE H

METEOROLOGICAL DATA __ JUNE - AUGUST 1968



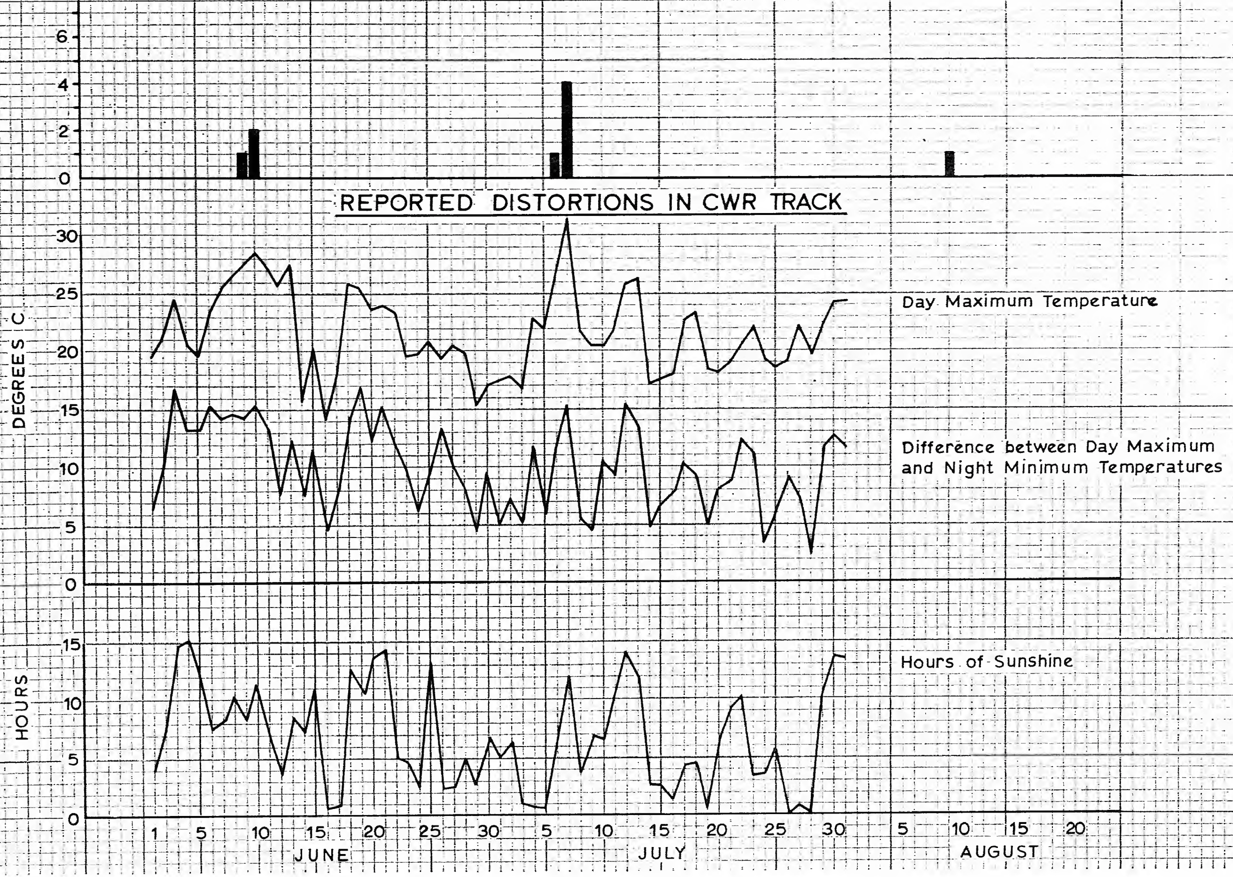
ANNEXURE I

METEOROLOGICAL DATA — JUNE-AUGUST 1969



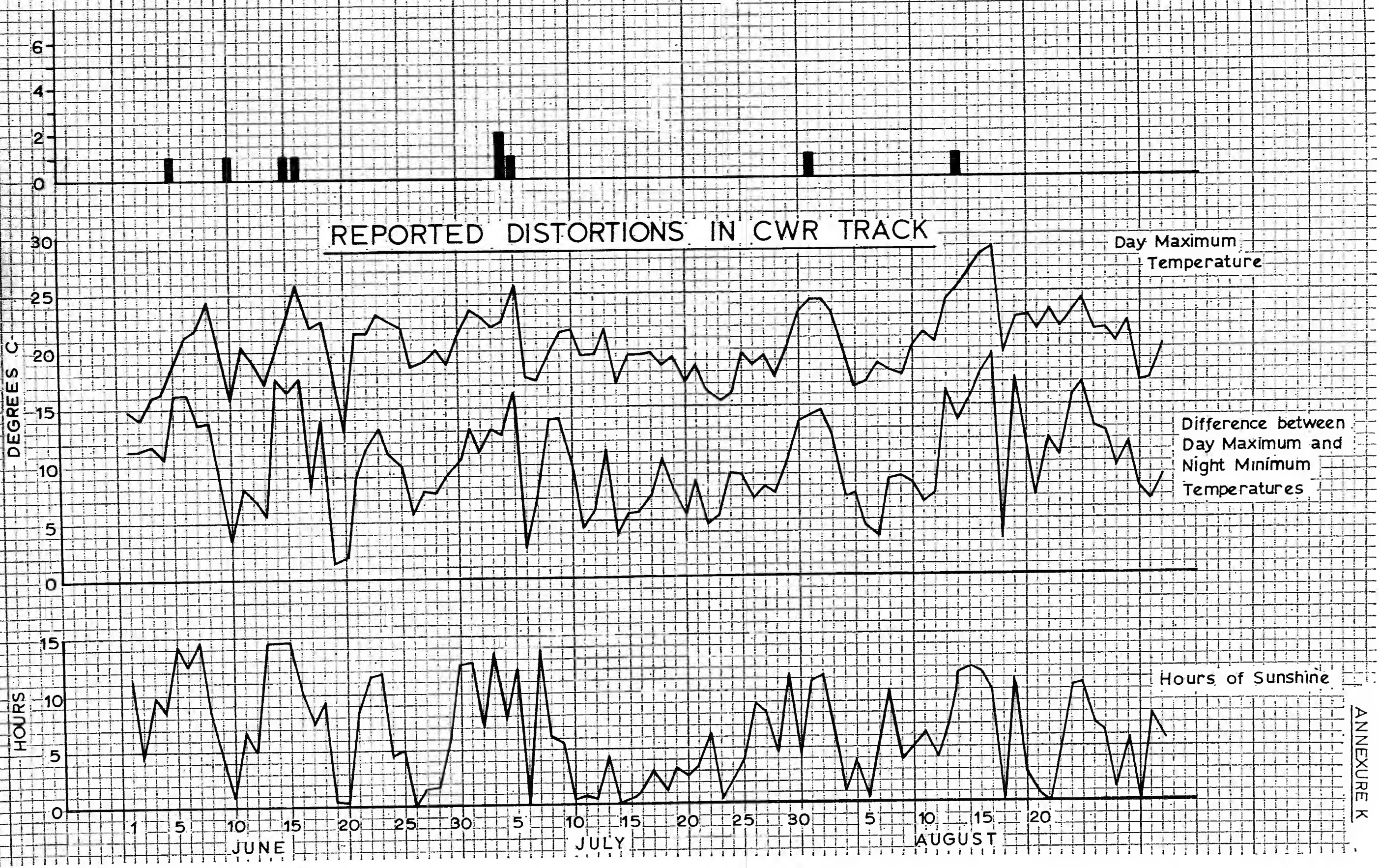
ANNEXURE J

METEOROLOGICAL DATA — JUNE–JULY 1970



ANNEXURE K

METEOROLOGICAL DATA — JUNE - AUGUST 1973



DEPARTMENT OF THE ENVIRONMENT

RAILWAY ACCIDENTS

Final Report
on the Derailments that occurred
on Continuous Welded Rail Track
at Lichfield (London Midland Region),
Somerton (Western Region),
and Sandy (Eastern Region),
British Railways, during June and July 1969,
and on the General Safety of this form of Track

LONDON: HER MAJESTY'S STATIONERY OFFICE
1974

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ISBN 0 11 550322 6

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RAILWAY INSPECTORATE,
DEPARTMENT OF THE ENVIRONMENT,
2 MARSHAM STREET,
LONDON, S.W.1.

31st January 1974.

SIR,

1. I have the honour to present, for the information of the Secretary of State and in accordance with the Order dated 17th June 1969, my final report on the derailments that occurred on continuous welded rail track at Lichfield, Somerton, and Sandy during June and July 1969, and on the general safety of this form of track.

2. The Order of 17th June 1969 appointed me to inquire into the derailment of an express passenger train that had occurred on 13th June 1969 at Somerton in the Western Region of British Railways. The terms of reference of this Order were extended, by amendments dated 14th and 24th July 1969, to include the derailment, on 10th June 1969, of an empty car-flat train at Lichfield in the London Midland Region, the derailment of a passenger express train near Sandy in the Eastern Region on 23rd July 1969, and the general safety of continuous welded rail (CWR) track.

3. It was clear at the time that a full investigation of the three train accidents and of all the circumstances that had led to the sharp and sudden increase in the number of CWR distortions reported during 1969 would take some considerable time. It was equally clear that the succession of accidents, two of which had involved the derailment at high speed of passenger expresses, had led to a questioning by the public of the basic safety of CWR track and that some form of reassurance, if indeed this could be given, should be given quickly and preferably before the onset of hot weather in 1970. My preliminary investigations, and a consideration of the urgent measures being taken by the Railways Board to improve the situation, led me to believe that the high level of distortions experienced in 1969, with the attendant risk of accident, would not be repeated and I gave this as my conclusion in an interim report which I submitted on 16th February 1970 and which was published on 2nd April 1970. I am glad to report that this reassurance proved well founded: the number of CWR distortions fell from a total of 48 in 1969 to only 9 during 1970 and the numbers have remained small each year since then. No further accidents resulted from the buckling of CWR until 19th July 1972, when a passenger train became derailed on distorted CWR near Cumbernauld in the Scottish Region. This accident, which I describe in paragraphs 33 to 41, demonstrated once again the vital importance of maintaining CWR track to the required standard: in this case standards had slipped and with them the safety margins against buckling.

4. In my interim report I indicated that the programme of investigation and research being undertaken by the Chief Civil Engineer's Department, British Railways Board, and the Railway Technical Centre, Derby, into the behaviour of CWR track and associated problems would take a considerable time, perhaps as much as two years. In the event some of the work has taken even longer and whilst there is now sufficient information available to enable me to conclude my Inquiry some of the research work is still continuing. The results of this are not however likely to affect my general conclusions although they may lead in time to further changes in the design of CWR track and in the methods of maintaining it.

5. In this final report I bring up to date the analysis of CWR distortions and the account of the measures taken by the Railways Board given in the interim report, review the train accidents at Lichfield, Somerton, Sandy, and the later accident at Cumbernauld, describe the results of research work into the behaviour of CWR track, and discuss the reasons for the sudden increase in CWR distortions that occurred in 1969. I then give my conclusions and recommendations.

TRACK DISTORTIONS ON BRITISH RAILWAYS 1958–1973

6. In the interim report I described the circumstances that had led to the adoption of CWR track as the standard for main lines and intensively used commuter lines on British Railways, and showed in a table the distortions that had occurred in CWR and jointed track. Table 1 overleaf shows the situation as at the end of 1973.

7. The table shows clearly the isolated nature of the CWR figures for 1969, so out of step with the general trend both before and after this year. It also shows the excellent performance of the CWR lines since 1969, in that the rate of distortions per 1,000 miles of track has been generally lower than the comparable figure for jointed track, a reversal of the situation that existed prior to 1969.

TABLE 1

Year	Track Mileage Jointed Track	Track Mileage CWR Track	Distortions on Jointed Track	Distortions on CWR Track	Distortions per 1,000 miles per annum	
					Jointed Track	CWR Track
1958	33,953	117	6	1	0·18	—
1959	33,335	201	48	6	1·44	—
1960	33,076	343	15	Nil	0·45	—
1961	32,308	664	24	2	0·74	—
1962	31,300	1,025	18	3	0·58	2·93
1963	30,258	1,392	33	6	1·09	4·32
1964	28,555	1,791	19	3	0·67	1·67
1965	26,450	2,346	18	2	0·68	0·85
1966	23,953	2,885	22	5	0·92	1·73
1967	22,345	3,387	27	6	1·21	1·77
1968	20,480	3,939	22	7	1·07	1·78
1969	18,490	4,605	55	48	2·98	10·42
1970	17,800	5,295	34	9	1·91	1·70
1971	17,020	5,927	25	5	1·48	0·84
1972	16,520	6,410	11	4	0·67	0·62
1973	15,624	7,018	18	9	1·15	1·28

NOTE: Track mileages do not include points and crossings. CWR mileage includes track laid in serviceable rail.

Analysis of CWR Distortions

8. In paragraph 7 of the interim report I gave the results of an analysis by cause of the CWR distortions that had occurred during 1969. This showed that unsatisfactory ballast conditions (lack of consolidation, voids, dirt, etc.) was the largest single cause of buckling and that the other main causes were failure to comply with the code of practice and faults associated with discontinuities in the line such as catchpoints and insulated joints. Table 2 gives the results of a similar analysis of the distortions that have occurred since 1969, compared with the 1969 results. It shows that unsatisfactory ballast remains the principle cause, and that the relative proportions of the various kinds of fault or failure that lead to distortion have not changed significantly.

TABLE 2

Cause of CWR Distortion	1969		1970–1973	
	Number	Percentage	Number	Percentage
Unsatisfactory ballast conditions	17	35	12	44
Failure to comply with code of practice	13	27	7	26
Faults associated with track discontinuities	11	23	5	19
Colliery subsidence	2	4	—	—
Other causes or cause not determined	5	11	3	11

9. Most of the 1969 distortions, in both CWR and jointed lines, occurred during two relatively concentrated periods, each of a few days duration. This pattern has been equally marked in the years since 1969. In 1970, for example, some 70 per cent of the year's total distortions occurred during the course of 4 days: three consecutive days in June and one day in July. Annexure A at the back of the report shows the distribution by date of all distortions, in CWR and jointed track, reported in 1969, 1970, and 1971. Figures for years prior to 1969 and since 1971 show much the same pattern.

10. In searching for the underlying reasons for the occurrence of distortions during these concentrated periods it proved useful to plot where they were occurring. Annexures B to F show the geographical distribution of all distortions, CWR and jointed, occurring in the main periods identified in Annexure A.

11. Further analysis of the time of day at which distortions occurred confirmed the pattern observed during 1969. Annexure G shows the time of occurrence of all CWR distortions in the period 1968–1973 and it will be seen that no distortions were reported before 12.00 (BST) but that thereafter the numbers increased rapidly to a peak between 14.30 and 15.00, the frequency then declining gradually until 19.00, after which only one isolated distortion occurred.

12. Another very significant factor proved to be the age of the track. Analysis of the 75 CWR distortions reported in the 5-year period 1969–1973 produced the following results:

Number of Distortions	*Percentage of Total*	*Age of Track*
32	43	Less than 1 year
7	9	1 to 2 years
4	5	2 to 3 years
9	12	3 to 4 years
6	8	4 to 5 years
4	5	5 to 6 years
6	8	6 to 7 years
2	3	7 to 8 years
5	7	over 8 years

Further analysis of the distortions occurring in track that had been in service for less than a year showed that the rate in track less than 6 months old was over twice that of track between 6 and 12 months old.

13. The preceding analysis serve to show the kind of factors that have influenced the occurrence of distortions in the past. They show the relative importance of various deficiencies in the track and suggest strongly that age of track and meteorological conditions play an important part in determining whether distortions happen or not. The meteorological factor was evident at the time of publication of the interim report but it was far from clear at that time what form this took. It seemed unlikely that maximum temperature alone could be the critical factor since temperatures as high, or nearly as high, as those recorded in 1969 had been experienced during 1968 and yet few buckles had resulted. I was unable to go further in the interim report than to say that "some factor in the meteorological conditions over central England during June and July 1969 searched out an unsuspected weakness in the CWR track as laid on British Railways". I reported that examination of the meteorological factors was continuing.

14. Until these meteorological factors had been properly investigated it was obvious that no answer could be given to the question of why 1969 saw such a dramatic jump in the number of CWR distortions compared with previous years. In the event the analysis of meteorological data had to be viewed in the light of other investigations, into rail temperatures and rail stresses for example, and since these various factors are so closely interrelated I discuss them after describing the progress made in research as a whole—see paragraph 54 et seq.

TRAIN ACCIDENTS

15. To date a total of seven trains have been derailed on British Railways as a direct result of the heat distortion of CWR track. Details of these accidents are given in Table 3 overleaf.

16. At the time of the publication of the interim report it was suspected that the derailment of a freightliner train, on 15th July 1969 at Grantshouse in the Scottish Region, was also due to the buckling of CWR track. After long and careful study however the Railway Officers concluded that the basic cause of this accident was a loose tyre on one of the freightliner wagons and that the track distortion that was observed after the derailment was a consequence and not a cause of the accident.

Accidents involving Freightliner trains

17. It will at once be noted from Table 3 that three of the seven derailments involved freightliner trains. In his report on the accidents at Berkhamsted and Auchencastle, Colonel Reed examined the possibility that track effects and forces imposed by the freightliner wagons might have been significant factors in the track buckling and he reported the results of tests arranged by the then Chief Engineer (Traction and Rolling Stock), BRB, to recheck the riding qualities of these wagons. The tests showed that although the vehicles could exert fluctuating lateral and vertical forces on the track of considerable magnitude there was no evidence that these were outside acceptable limits for main line track at speeds up to 75 m.p.h., but that for ordinary jointed track where the line speed was 75 m.p.h. or less freightliner trains should be restricted to about 5 m.p.h. below line speed. Further trials and design investigations were proposed.

18. In June 1969 the derailments at Lichfield and Somerton focussed attention once more onto the buckling of CWR track and although neither of these accidents involved a freightliner train the next derailment, at Lamington on 15th July 1969, did. This accident was not included in the extended terms of reference of my Inquiry into the Somerton derailment but the full reports on it submitted by Scottish Region were closely studied by Colonel Reed and myself and we visited the site together and discussed the circumstances

TABLE 3

Serial	Date	Place	Region	Type of Train Derailed	Remarks
1	12 June 68	Berkhamsted	LM	Diesel loco hauled Freightliner	Inquiry Report by Col. W. P. Reed published October 1969
2	14 June 68	Auchencastle	Sc	Diesel loco hauled Freightliner	Inquiry Report by Col. W. P. Reed published October 1969
3	10 June 69	Lichfield	LM	Electric loco hauled empty car-flats	See para. 20
4	13 June 69	Somerton	W	Diesel loco hauled passenger express	See para. 25
5	15 July 69	Lamington	Sc	Diesel loco hauled Freightliner	See para. 18
6	23 July 69	Sandy	E	Diesel loco hauled passenger express	See para. 28
7	19 July 72	Cumbernauld	Sc	Diesel multiple-unit passenger train	See para. 33

with the Railway Officers in Scotland. The respective contributions of train and track towards this accident were if anything even more difficult to assess than in the case of the two earlier freightliner accidents. At Berkhamsted the track had not been destressed since it was laid, in freezing conditions, some six months before the accident, and at Auchencastle the track had been disturbed during the four previous weekends by sleeper changing and refettling. But no comparable irregularities could be found at Lamington. The track appeared to be in good condition in all respects. It had been laid with 113 lb/yd CWR on concrete sleepers with Pandrol fastenings in March 1969 and destressed to a stress free temperature of 21°C on the same day. Tests after the accident revealed that the cess rail had a stress free temperature of 21°C whilst the six-foot rail was stress free at 18°C so that no dramatic lowering of the stress free temperature had occurred. The rail temperature, taken soon after the accident, was 34°C. Ballast conditions were excellent and the track was straight on a falling gradient of 1 in 200, and on a low embankment. The only departure from standard was the presence, very close to the point at which the distortion started, of five timber sleepers which had been inserted, in place of concrete sleepers, in order to take the securing screws of an AWS magnet. The freightliner train, which was unevenly loaded along its length, was travelling at about 70 m.p.h., i.e. about 5 m.p.h. below its permitted speed of 75 m.p.h., which was also the line speed limit. No defects were found on either the train locomotive or on any of the wagons, but one container on the second vehicle and one on the seventh were not properly secured because the twist locks had not been fully turned. Each of these containers was therefore free to 'bounce', with an unsprung weight of nearly 11 tons and just over 7 tons respectively. The track buckling developed under the middle of the 15-wagon train and the tenth wagon was the first to derail.

19. The accident at Lamington brought the total of derailments on buckled CWR to five. In the two accidents not involving freightliners the track had been seen by the drivers to be buckled ahead of the train, but in all three freightliner accidents the track had buckled suddenly under the train itself. Moreover, each of the freightliner trains had consisted of 15 wagons and in each case derailment had commenced towards the rear of the train. There was thus a strong suspicion that CWR track might be especially vulnerable to the riding of freightliner wagons, and tests to determine the track forces produced by these wagons were intensified. The tests continued well into 1970 and confirmed that certain aspects of the ride were unsatisfactory, especially that of unladen bogies. Various modifications were proposed, and although these did not entail extensive alterations they did entail lifting the wagons so that the modification programme would clearly take some time. As the work could not even start until well into the summer of 1970 the Board imposed a 65 m.p.h. speed limit on all freightliner trains throughout that summer, running from noon until 21.00 each day, and this was continued during the summer of 1971. The modification programme was completed in the Spring of 1972 and the speed restriction was not reimposed. There is no doubt that the modifications have produced a significant improvement in the riding qualities: some measure of this can be obtained from the fact that wheel wear has been reduced and the intervals between wheel turning have been considerably increased in consequence. And there have been no further freightliner derailments on buckled CWR, although in June 1973 a freightliner derailed at speed on *jointed* track that buckled under it at Berkhamsted. I am conducting a separate Inquiry into this accident.

The Derailment at Lichfield on 10th June 1969

20. In the interim report I described the circumstances of this accident, in which a train of empty car-flat wagons hauled by an electric locomotive became derailed on CWR track just north of Lichfield, and said that I was satisfied that the direct cause of the accident was a distortion of the CWR. I was unable to be as positive about the cause of the distortion and limited myself to listing some eight factors that could have been significant.

21. Further studies and tests carried out since publication of the interim report have not thrown much further light on the cause of the distortion. One of the fundamental difficulties is that it is impossible to say with any certainty what the stress conditions were in the rails immediately before the distortion started, although the evidence available at the time did not suggest that there had been any significant lowering of the stress free temperatures: readings taken when the track was destressed in October 1968 indicate that little or no alteration had taken place during the four and a half years that the track had been in service and it is unlikely that cold-rolling or wear could have produced significant stress changes thereafter. Similarly there are no real grounds for suggesting that the destressing was other than properly carried out, although the procedures adopted were not strictly in accordance with the standards now set and there must always be the possibility that some movement took place in the point and crossing work that was being used as an anchorage. No tell-tale marks were established in the anchorage and thus no evidence was available on the presence, or absence, of movement in it.

22. The possibility that the rails might have been damaged or overstressed when the track was opened out for reballasting remains an interesting theory, but calculations show that the deformation would have had to be severe before permanent damage would be done. Nevertheless the fact that the 'hinge' formed when the rails were moved outwards and downwards was so close to the point at which distortion later occurred strikes me as significant.

23. One possibility that was not mentioned in the interim report was that creep in the Down line might have reduced the stress free temperature or served to 'unlock' the sleepers. When rails creep towards an anchorage this reduces the stress free temperature, and the Down line in the area of the derailment was on a gradient rising away from a substantial anchorage—the strengthened point and crossing work. In addition, had there been any tendency for the rails to creep, the SHC fastenings, which have a relatively high creep resistance, might have transmitted the motion to the sleepers and it is possible that any such movement of the sleepers along the axis of the track might lead to a reduction in their resistance to lateral motion. All this however is speculative, since there was no clear evidence of creep at the time of the accident.

24. In conclusion, I think that this distortion was caused by the chance coming together of a number of factors each working to reduce the safety margin against lateral instability. I think it most likely that the stress free temperature, for some reason, was considerably lower than the 24°C that had been measured in October 1968 and that the consequent temperature forces were sufficient to overcome the ballast resistance, which might well have been less than expected because of voids—the track structure was to some degree suspect—and possibly the effects of creep.

The Derailment between Somerton and Castle Cary on 13th June 1969

25. The circumstances of this accident, in which a Paignton to Paddington express derailed at nearly 80 m.p.h. on CWR track, are also described in the interim report. There is no doubt that this accident was caused by a severe distortion in the track: a misalignment of between 12 and 24 inches was clearly seen by the driver and secondman of the express as they approached and it had the characteristic 'S' shape of the classic heat buckle.

26. There is similarly little doubt as to the cause of distortion. The experiments on ballast resistance conducted since 1969 have shown clearly that the lateral resistance of the track in this case must have been very significantly lowered during the track operations connected with the bridge reconstruction and that the subsequent failure to destress fully into the disturbed length must have left a weakened area of the track at exactly the point where the distortion eventually developed. I am satisfied that these circumstances, which are fully described in the interim report, provide a good and sufficient explanation for the distortion.

27. I should perhaps qualify my use of the word 'failure' in connection with the destressing. When the work was carried out in November 1968 it was done generally in accordance with the instructions then in force, apart from the actual deployment of the rail warmers. The engineers responsible were doing what on the face of it seemed a routine piece of work and, bearing in mind the state of the art at the time, it would have needed some insight on their part to have predicted the likely effects of the bridge reconstruction on the track stresses. I do not feel that they can justly be criticised for not having spotted the danger.

The Derailment near Sandy on 23rd July 1969

28. In this accident, which is fully described in the interim report, a King's Cross to Newcastle express—the Tees–Tyne Pullman—became derailed at over 90 m.p.h. on CWR track. As in the case of the accident near Somerton the track was seen by the train driver and his secondman to be badly distorted and again the size and shape of the distortion left no doubt that it was a heat induced buckle.

29. The design, construction, and maintenance history of the track showed no obvious deficiencies from the stability point of view, and in most respects it was typical of many miles of similar track on the East Coast Main Line, all of which had been trouble free for many years. There were however a number of individual features which could have been significant and these are listed in paragraph 57 of the interim report.

30. Most of the trials and tests conducted shortly after the accident concentrated on the rail fastenings since it was felt that the somewhat unusual combination of Mills C1 and Mills C3 clips might have had something to do with the buckling. In the first experiments, in-situ tests were made on six lengths of track in the immediate vicinity of the derailment and, for comparison, on four other lengths some 40 miles further north on the main line. The tests were designed to check the lateral resistance of the track both in 'as found' condition and with some degree of ballast loosening introduced, and included track with various combinations of Mills clips, Pandrol, and SHC fastenings, on timber and concrete sleepers. The trials showed convincingly that the Mills C1/C3 combination was not inferior to any of the other timber sleeper assemblies. One interesting feature was the close similarity between all the test results, which were remarkably constant bearing in mind the intrinsic scatter normally associated with ad-hoc tests of this nature. This was thought to be due to the consistently high quality and quantity of the ballasting, the effects of which largely outweighed any differences caused by the fastenings. In general the concrete sleepers gave better lateral resistance than the timber, irrespective of the fastenings, but the differences were fairly marginal.

31. During the examination of the track after the accident it was noticed that some of the baseplates in the distorted length had their shoulders chipped. This could have been caused by pressure from the rails as they tended to distort, either thermally or under the action of traffic passing over an initial small misalignment, or both, and the thought arose that the rails might have become partially released from the baseplates prior to the derailment. In order to investigate this possibility sample sleeper and fastening assemblies were taken from the distorted track to the Railway Technical Centre at Derby and tested to see whether any weakness due to wear, particularly in the C1 assemblies, could have led to rail/sleeper separation under traffic. The assemblies were tested with inclined, torsional, and vertical loads tending to tip, twist, and lift the rails out of the fastenings and loads were applied either until the fastenings failed or until the test rig reached its limits. In the inclined load tests the C3 assemblies showed considerably greater stiffness and much lower loss of toe load, but it nevertheless proved quite impossible to force the rail out of the baseplates, even with the weakest of the C1 assemblies. In the torsional and the vertical lifting tests the worn C1 assemblies produced almost as good figures as the best of the C3s. The results thus gave no support to the idea that the rails might have separated from the baseplates before derailment.

32. No further evidence has come to light concerning the other matters identified and listed in the interim report. As in the Lichfield accident the main difficulty is the lack of any real evidence on the stress conditions in the rails immediately prior to the development of the distortion. Rail temperatures were undoubtedly very high in this case and in the absence of any obvious deficiency in the track or its ballasting there must be a strong suspicion that the stress free temperature was in fact considerably lower than expected. The history of alterations to the track at or close to the site of the accident, with the attendant pattern of destressings, might well provide a reason for this, although the matter must remain conjectural. For the rest, I continue to suspect that the quite unusual pattern of side cutting that I mentioned in the interim report was a significant factor and that this was evidence of a weakness in the track, sufficient to trigger a distortion once the thermal forces had become sufficiently great.

Derailment near Cumbernauld, Scottish Region, on 19th July 1972

33. In paragraph 3 I mentioned that since 1969 only one train accident has been caused by the buckling of CWR track and that this was the derailment of a passenger train near Cumbernauld, on the line between Glasgow and Stirling, on 19th July 1972. The accident happened at about 14.00 on that day when the rearmost coach of the 13.47 Springburn to Cumbernauld train composed of 1 × 3-car and 1 × 2-car diesel multiple-unit sets became derailed all wheels on buckled CWR track in the Down line. The train was travelling at about 65 m.p.h. at the time but although the derailed coach became bufferlocked with the one ahead it remained upright and in line whilst the driver brought the train to a stand some 530 yards further on. Four passengers were slightly injured and several others suffered shock. The weather at the time was dry and very warm.

34. The track had already started to buckle before the train arrived on it and the misalignment, which was initially quite small, was seen by the train driver as he approached. There was insufficient distance in which to stop before reaching the misalignment and, sensibly, the driver decided not to brake but merely to close the throttle in the hope that the train would pass over the buckle. The track deformation however got progressively worse during the passage of the train and it had grown sufficiently by the time the last coach arrived on it to derail the trailing bogie: derailment of the leading bogie then followed, together with further distortion of and damage to the track.

35. The section of track where the derailment occurred was formed of 110A CWR on type F.23 concrete sleepers (26 to the 60 ft length) with BJB fastenings and was laid in 1962. A small length of track in the vicinity of the former Lenziemill level crossing, which is some 300 yards in the Down direction beyond the point of derailment, was laid in 1969 with similar rail and sleepers but with Pandrol fastenings. The ballast consisted mainly of whinstone with a little slag intermixed with it. Near the point of derailment the Down line runs in a north-east direction: it is straight, on a gradient of 1 in 99, and the actual point of derailment was near the northern end of a shallow cutting. The maximum permissible line speed at the time of the accident was 70 m.p.h.

36. Records show that, when laid in 1962, the length of track concerned had been destressed to give stress free conditions somewhere in the temperature range 18·3–24°C. It had not been subsequently destressed. About 170 yards on the Glasgow side of the centre of the distortion the railway is carried over a motorway on a large bridge. In 1966, as part of the bridge construction works, breather switches were placed in the track on each side of the bridge and when these were removed in January 1967 the track was destressed to 24°C, this being carried out over a distance of 100 yards on each side of the bridge. Breather switches had also been provided in the Down line on both sides of Lenziemill level crossing and when these were removed, in August 1969, the track had been destressed to 26·7°C for a distance of 150 yards on both sides of the crossing. The buckle thus occurred in a length of line, about 200 yards long, which had not been destressed since 1962 and which was flanked on either side by lengths that had been destressed at later dates and to higher stress free temperatures.

37. The formation near the point of derailment was on clay and the track had needed fairly frequent attention because of wet spots and pumping. Examination after the accident revealed the presence of a mixture of clay-bound stone and dirt below the sleepers which was very hard, with marked shrinkage, when dry but which became soft when wet. These conditions extended for at least 8 ins below the bottom of the sleepers and would have led to the presence of voids. The track in the immediate vicinity of the point of derailment had been tamped on 4th June 1972 and some hand packing and hand cleaning of the ballast had been undertaken in the area on or about 10th June.

38. The condition of the track was closely checked immediately after the accident and apart from the physical condition of the ballast below sleeper level there was also a serious shortage of shoulder ballast over a length of 50 to 60 feet. The specification at the time, as now, called for 15 inches of ballast on the shoulder, heaped as far as possible at the sleeper ends, but in this case the shoulder was not more than 7 inches wide, with little or no heaping. In all other respects the track appeared to be up to specification. The deficiency of ballast had been noted by the Area Civil Engineer on 30th June during a visit to this part of the line, but although arrangements were in hand for the supply of additional ballast it had not been provided by 19th July.

39. Rail temperature at the point of derailment was recorded soon after the accident as 39°C. A meteorological station at Cumbernauld recorded the minimum air temperature during the night of 18/19th July as 11°C and the maximum day air temperature as 26°C. Calculations showed that with a stress free temperature of something less than 20°C and the ballast conditions as stated the track could well have been in a sensitive condition with rail temperatures around 40°C.

40. Examination of the train failed to reveal any faults that might have contributed to the accident. The last train to pass over the Down line before the 13.47 from Springburn was the 13.15 from Springburn, also a diesel multiple-unit, which arrived at Cumbernauld at 13.32 without its crew being aware of any fault in the line.

41. The evidence shows that a slight misalignment of the track existed before the 13.47 train arrived and that this got progressively worse as the train passed over it, the deformation being ultimately sufficient to derail the last coach. There is little doubt that the initial misalignment was the first stage of a heat-induced buckle, brought about by the generally unsatisfactory ballast conditions, with voids below the sleepers and insufficient shoulder stone. Although the ballast deficiences were known and some action was being taken it seems surprising and regrettable that, despite the lessons learned at such cost during 1969, such deficiencies in a section of CWR track should have been allowed to remain unremedied for nearly three weeks in the middle of summer. The accident serves as a forceful reminder that CWR track is only stable during hot weather when it is maintained properly in accordance with the standards set.

MEASURES TAKEN BY THE BRITISH RAILWAYS BOARD

42. Following the two derailments of freightliner trains on buckled CWR track during 1968 the Railways Board put in hand certain measures. The main ones were directed towards determining the actual stress free temperature of existing lengths of CWR track, and investigating the riding characteristics of freightliner vehicles. The progress of the latter investigation has already been described in paragraphs 17 and 19 of this report. The track investigations were still continuing when the spate of distortions started in the summer of 1969 and the Board took immediate action to contain the situation: a full account of the measures taken is given in paragraph 65 of the interim report. The undoubted success of these measures is shown by the track distortion figures for the years subsequent to 1969 given in Table 1 on page 6.

43. The following notes bring up to date the account of the more important measures given in the interim report.

(*a*) *Ballasting Programme*. The crash programme to add additional ballast, up to the new standards laid down by the Board's Chief Civil Engineer in July 1969 (as described in paragraph 65(*b*) of the interim report), continued well into 1970. It was a very large-scale operation, involving the closest co-operation between the civil engineering and operating departments, but by the onset of warm weather in 1970 virtually all the CWR lines had been strengthened. There can be no doubt that this programme played a major role in restricting the number of distortions in early 1970, i.e. before the other measures being taken could be completed.

(*b*) *Destressing Existing Track.* As described in paragraph 65(*c*) of the interim report a special exercise was launched in July 1969 to destress all lengths of CWR in which the stress conditions were at all suspect. This also was a large-scale operation and work continued until the early summer of 1970, by which time most of the suspect lengths had been covered. The programme has continued since 1970: whenever grounds have arisen for suspecting any length, e.g. when following realignment or a derailment CWR track has been displaced, the length is destressed. This has led to considerably more destressing than was the practice before 1969.

(*c*) *Revision of the Code of Practice.* As forecast in the interim report the code of practice for installing and maintaining CWR track—Civil Engineering Handbook No. 11—was extensively revised and a new edition was issued in March 1970. It incorporated all the changes listed in paragraph 65(*d*) of the interim report and also included clear and precise instructions on destressing. It is in every way a more positive and exact code than its predecessor and provides the permanent way engineer and supervisor with a clear blueprint for safe CWR track.

(*d*) *Meteorological Data.* The revised Civil Engineering Handbook No. 11 lays down strict conditions for the maintenance of CWR during hot weather and the planning of such work now requires accurate forecasting of weather conditions. By arrangement with the Meteorological Office forecasts of temperature, wind conditions, and cloud cover for the next three days are sent before 09.00 each morning between the beginning of April and the end of September to designated civil engineering offices throughout the country. The forecast is provided by the nearest weather station and enables the engineer to alert his supervisors whenever weather conditions are likely to restrict work on the track. As described in paragraph 46 of this report, data is available by which the meteorological forecast can be used to predict the likely maximum rail temperature.

RESEARCH WORK

44. Paragraphs 66, 67, and 68 of the interim report described the programme of research and testing being conducted jointly by the Board's Head of Research and Chief Civil Engineer and mentioned that parts of the programme were essentially long term. Two years was quoted as the time-scale for some of the experiments and, in the way of such estimates, this proved to have been slightly over optimistic and part of the work is still incomplete. Nevertheless, a great deal of most valuable work has been done and much more is now known about the behaviour of CWR track and of its special problems. This is not to say that any dramatic "breakthrough" has been made: the experiments and trials have rather served to confirm the basic soundness of the theoretical and practical studies that had been made before, although they have focussed attention on some aspects that were perhaps not sufficiently appreciated prior to the events of 1969.

45. One set of experiments was concerned with *temperature relationships*. Not much was known about the relationship between ambient temperature, especially in a changing weather situation, and actual rail temperature, nor was it certain that rail temperatures as measured with the rail thermometers in current use were really accurate. Dealing with the second problem first, the contact thermometers used on British Railways are of two types: a mercury thermometer in a copper encasement, and a dial type with a magnetic contact to the rail. The latter is the most common, and experiments were carried out in the laboratory to check its performance against thermocouples embedded in a length of rail. The experiment simulated solar radiation equivalent to that of a midsummer day and various strengths of wind. The results showed that heating by direct radiation on one side of the rail produced very little variation in temperature across the rail head and between the head and the web even with a wind blowing, but that the foot of the rail remained about 2°C below the temperature in the head irrespective of wind conditions. Comparisons between the web-mounted rail thermometer and a thermocouple in the centre of the rail head were therefore valid. It was found that in all cases the rail thermometer reached equilibrium with the rail in less than 15 minutes but that discrepancies then existed between the thermometer reading and the true rail temperature and that these were maintained indefinitely. In most cases the readings were too low, several combinations of sun, shade, and wind producing dial readings 4°C below true rail temperature. In only one case was the thermometer found to be reading too high, and this was by 1°C only. The results thus showed that the use of dial type thermometers during destressing operations could result in the rail's stress free temperature being some 4°C (7°F) above that designed. Modifications to the thermometer have been proposed which should reduce the margin of error.

46. Regarding the *relationship between ambient air temperature and rail temperature* records of rail temperature kept over many years by London Transport Railways were made available to the Board's Chief Civil Engineer in 1969. These showed in graphical form the actual maximum rail temperatures recorded in the London area and the highest observed excess of rail temperature over air temperature (measured 4 ft above ground level) during a 14 year period. Use of these curves enables forecast air temperatures to be converted into likely maximum rail temperatures, due allowance being made for other conditions such as wind, cloud cover, and geographical location. Since 1969 the Board's Chief Civil Engineer has compared data collected from all over the country with that shown on the curves and is satisfied that the latter gives an acceptably accurate indication of the maximum excess of rail temperature over air temperature likely to be encountered anywhere on BR.

47. Another set of field experiments investigated the *cold-rolling* or *lengthening of rails in service.* The possibility that compressive longitudinal forces might be induced in rails by some 'rolling-out' effect or by repeated braking or by a combination of the two had long been suspected and the tests conducted in Scottish Region, mentioned in paragraph 63 of the interim report, showed that the effect might be widespread. Any such force would of course have the effect of lowering the stress free temperature and thus be significant in CWR track. The experiments started in November 1970 and involved extremely precise measurements of strain in rails specially installed in a section of the heavily trafficked line between Retford and Worksop. The programme was essentially long term with the first stage designed to continue for about two years. At the time of writing the work is not complete, but some preliminary results are available. These show that new rails undoubtedly try to 'grow' for a number of weeks after being placed in the track as a result of plastic deformation of the rail head. In practice the rail is laid flat and held flat by the fastenings and it is thus not possible for the rail head and foot to change length to a different degree: they must undergo the same changes in length. However, the plastic deformation of the head increases the natural length of the material, i.e. the length it would have if it were cut out of the rail and there is thus a build up of compressive stress in the head to suppress this increase in natural length. The compressive stress is balanced by a corresponding tensile stress in the lower part of the rail. In continuous rail, where adjustment of length is wholly prevented, the effect of these 'rolling-out' stresses is to cause a reduction in the effective stress free temperature. During the tests values of strain were obtained which were equivalent to a reduction in stress free temperature of as much as 19·4°C during the first 20 weeks in service and whilst this was regarded as an extreme case it seems that values as high as this cannot be completely ruled out in practice. Further experiments designed to confirm the presence of these high strain values and to discover how frequently they might occur in practice are continuing. It should perhaps be emphasised that, whilst there seems little doubt that effects such as those observed during the experiments do occur in practice, opinion is somewhat divided on the actual mechanisms involved. Further work is clearly needed.

48. In line with the investigations into 'cold-rolling' has been the development of a *Rail Force Transducer* for the 'in-situ' monitoring of the longitudinal force in a rail. Prototypes of this device have been tested in service under moderately severe traffic and show considerable promise. They have given consistent and reliable results when used in rails that have undergone full 'cold-rolling', and have proved acceptably robust in service. Final proving trials of the transducer are in progress, as are tests to determine whether it will detect change of stress free temperature due to rolling out of new rails. A successful force measuring device that is independent of rail temperature readings will provide a most useful check on the validity of the conventional methods.

49. Some of the research work concerned with *fastening resistance* has already been mentioned in connection with the Sandy accident (see paragraphs 30 and 31). Although the torsional restraint provided by fastenings constitutes only a small part of the total resistance to buckling this small contribution is most important when the lateral ballast resistance is reduced, say by the presence of voids, and under these conditions it can determine whether or not a distortion occurs. Attempts have therefore been made to determine the rotational stiffness of the fastenings in current use and to evaluate their contribution to stability. In this respect measurements made in the laboratory must be treated with caution since it is difficult to reproduce the dynamic effects of traffic or to allow properly for the reductions in toe load that occur in service. Nevertheless the results obtained have shown a significant variation between the performance of different kinds of fastening and demonstrated that low torsional stiffness figures sufficient to reduce the critical wavelength and increase the sensitivity of the track to buckling are likely to be common with some existing fittings.

50. In the interim report I described the then projected tests on *ballast resistance* as of fundamental importance. The ballast provides by far the largest contribution to lateral stability and the type and quantity of ballast, its interaction with the sleepers, its consolidation under traffic, and its reaction to disturbance are all matters of great importance. Much has been done since 1969 to study the behaviour of ballast and perhaps the most significant results have concerned the effects of disturbance of the ballast. Study of the distortions during 1969 had shown that many of the buckles occurred very soon after the track had been disturbed in some way: 38 per cent of the buckles that year were in track that had experienced some disturbance of the ballast during the previous 10 days, and in 65 per cent of the buckles the ballast had been disturbed during the previous 15 days. Static field tests showed that lateral sleeper resistance increases under traffic and that undisturbed track that has carried large volumes of traffic can be expected to exhibit very high lateral resistance values. Tamping, if done without consolidation, can reduce these values by 30 per cent or more and similar losses will result from other disturbances of the track, e.g. sleeper changing or lifting. If left alone the resistance then starts to increase quite rapidly under the influence of traffic and some three-quarters of the loss is regained after about a week, although thereafter the rate of recovery is much slower and even after a month the full resistance will not have been regained. The use of mechanical crib and shoulder consolidation after tamping helps to restore the lateral resistance (provided the ballast level is maintained at or above sleeper top level) although even with this some residual loss of resistance can be expected. One result obtained from laboratory trials was that significantly better values could be obtained with mechanical consolidation if the ballast in cribs and shoulders was placed 1 or 2 ins above sleeper top level before consolidation, thus ensuring that fully compacted ballast was in contact with the vertical surfaces of the sleeper over the full depth. These results suggest strongly that new track, even if carefully laid and fully ballasted, may need a relatively long period of consolidation under traffic before its full lateral resistance is developed. The clear influence of track age to its vulnerability to distortion, shown in paragraph 12 of this report, supports this view.

51. Some confirmation of the significance of ballast disturbance is available from work carried out in other countries. Thus tests carried out in Germany (reported in the Railway Gazette of 1 May 1970) showed that the loss of static lateral resistance following tamping could be as high as 70 per cent and that subsequent traffic loads of about 60,000 tons were required to restore even 30 per cent of this loss: some 250,000 tons were required before the original resistance was regained. The track in this case differed from that used in BR's experiments in that it included timber sleepers at relatively close spacing.

52. Parallel with the experimental work described in the preceding paragraphs some important *theoretical work* has been done. In June 1970 Mr. C. O. Frederick of the BR Research and Development Track Group at Derby produced a paper* that reviewed existing theories of track distortion and proposed a new method for calculating the stability of CWR track. The theory was modified and refined as results of experimental work became available and a revised version of the paper was issued in February 1973.

Comparison with Foreign Railways Design and Practice

53. In my interim report I compared BR's CWR design and practice with that of other European railways and showed that these were generally very similar, the most significant difference being BR's use of heavy concrete sleepers at a somewhat wider spacing than that adopted by most other administrations. Information has since been collected on practice in non-European countries, particularly in America and Japan where CWR track is used extensively. These have also shown a near unanimity in design and maintenance practices and broadly speaking the measure of success on these railways in combatting CWR distortion has been in direct proportion to the care and attention paid to sound specification and rigorous enforcement of maintenance standards and restraints. The Japanese in particular, with climatic conditions somewhat similar to our own, have achieved excellent results by virtue of their very close control of all work carried out on CWR track during hot weather.

The High Incidence of CWR Distortions During 1969

54. At the time of publication of the interim report there was some criticism in the technical press of the fact that I had not offered any explanation for the sudden increase in distortions that had occurred during 1969. As I have explained in paragraphs 13 and 14 of this report it was not possible in early 1970 to say with any certainty why the number of distortions had increased so dramatically, and I could only indicate the more likely factors. Indeed, at that time it was by no means certain that the same phenomena would not recur during the summer of 1970, and my interim conclusions had of necessity to be guarded.

55. One suggestion made when the interim report was published demanded serious consideration. This was that the number of distortions, especially in CWR track, had been much higher before 1969 than was generally supposed and that the derailments on buckled CWR during 1968 had led to many more distortions being *reported* in 1969 than would otherwise have been the case. The Inspectorate did, in fact, agree with the Board's Chief Civil Engineer a new definition of what constituted a reportable heat-induced distortion in November 1969, but detailed examination of the records for previous years with the Railway Officers has shown that with very few exceptions all distortions falling within the definition agreed in November 1969 were being reported prior to that date. Even assuming that 10 or 20 per cent of the actual distortions occurring before 1969 were not reported, and that a similar percentage of cases reported during or since 1969 would not have been reported before the definition was refined, the number of distortions in 1969 must still have been quite exceptional.

56. All the research and investigation carried out since 1969 has enabled a reasonably reliable picture to be drawn of the way in which the lateral stability of CWR track may be reduced, and of the actual mechanisms of failure. The following hypothetical sequence, applicable to track laid and maintained under conditions prevailing in the early summer of 1969, illustrates most of the factors now thought to be important:—

(*a*) A length of track has been in service for something less than a year. It was laid to a designed stress free temperature of 21°C but the methods of achieving this stress free temperature, although in accordance with the then current instructions, were such that some variation in the actual stress conditions was probable. The track has not subsequently been destressed.

(*b*) Wear and possibly cold-rolling effects, together with braking or creep movements and a slight displacement of the track (especially likely if the track is on a curve) have led to a lowering of the original stress free temperature. [All these modes of stress reduction are believed to take place and could be additional to any shortfall in the original designed stress free condition: their combined effects could theoretically amount to as much as 20°C, although half this figure would seem to represent a more likely maximum.]

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*BRB Research and Development Division. Track Group Technical Note TN. TS.4 'The Lateral Stability of CWR' by C. O. Frederick.

(*c*) The track is tamped, or the ballast otherwise disturbed, and no compaction or consolidation is carried out. There may be slight voids under some sleepers.

(*d*) The passage of traffic, especially hunting vehicles or those imposing high lateral forces, leads to the development of slight misalignments, possibly cyclic in character. These are very difficult to detect, and pass unnoticed.

(*e*) There is a marked change in the weather, characterised by a rise of 12°C or more in the ambient air temperature, spread over two or three days at the most. Differences between day maximum air temperature (occurring normally in mid-afternoon) and minimum night temperature (occurring normally near dawn) are large, and the difference between early morning ground temperature (which can produce frost conditions even in June) and mid-afternoon rail temperature are extreme. In addition, physical differences caused by shade, exposure to wind etc., lead to quite large variations in temperature along a given length of rail. The cyclic nature of these temperature variations has a loosening effect on the bond between sleepers and ballast, and some reduction in lateral resistance occurs. [Although there is as yet no direct evidence that such a loosening occurs there is strong circumstantial evidence that temperature cycling of this nature can cause a reduction in lateral restraint, and I believe that it does.]

(*f*) With maximum day temperatures now in the region of 25°C the rail temperature reaches 49°C (actual rail temperatures as high as 51·7°C have been recorded on BR). The track having been installed at a nominal stress free temperature of 21°C (the standard practice prior to mid-1969 was for track to be stress free at a temperature between 18·3°C and 24°C), the reduction by some 10°C of the stress free temperature, being the combination of the losses postulated in *b*, and any original shortfall in the designed stress free temperature, means that the rail is now some 38°C above its stress free temperature. With lowered lateral resistance and possibly less than perfect fastenings the safety margin against buckling has all but disappeared, and the slight misalignment suggested in *d*, may be sufficient to initiate a buckle, especially if it is present over something near the critical wavelength.

57. The values used in this hypothetical sequence have been chosen to represent a state of affairs that could well have occurred on occasions during 1969 or earlier years. In particular, the value of 38°C above stress free temperature is not likely to be an overestimation, and figures well in excess of 40°C could have been experienced. Thus, prior to the Board's 1969 measures to improve the stability of CWR track, there must have been a number of occasions each summer prior to 1969 when lengths of CWR track were approaching a critical condition, with safety margins reduced to very low levels.

58. It is against this background that one must examine the events of 1969 and try to detect the factor or factors that made this year different from previous years. I am quite satisfied that no change in the method of laying or maintaining CWR track, or in the type or volume of traffic passing over it, marked 1969 as in any significant way different from the immediately preceding years. Nor is there any evidence that the physical condition of the track changed in any way during that year—that, for example, some significant effect took place in track that was then completing ten years or more in service. One is left, therefore, with the inescapable conclusion that the critical factor, the one that finally tipped the scales in those cases where the track was already in a sensitive condition, was the exceptional weather pattern that characterised the long hot summer of 1969.

59. The Meteorological Office kindly supplied me with data relating to temperature, rainfall, wind, and hours of sunshine during the summer months of 1968–1973. The recording stations for this data were selected in the light of the geographical distribution of distortions shown in Annexures B to F. From a preliminary study it was clear that rainfall and wind were of marginal significance only, and graphs were therefore plotted showing the maximum day temperature, difference between maximum day temperature and minimum night temperature, and hours of sunshine, related to the occurrence of CWR distortions. Graphs for 1968, 1969, 1970, and 1973 are reproduced as Annexures H, I, J, and K. The significant comparison must be that between 1968 and 1969: subsequent to 1969 the measures introduced by the Board altered the situation fundamentally and comparison with earlier years could therefore be misleading. Comparing 1968 and 1969 however it is clear that maximum temperature alone cannot be the critical factor. Nearly all the buckles occurred whilst maximum day temperatures were above 22°C, but very high day temperatures alone did not necessarily lead to distortions. Twice during 1968, for example, day temperatures exceeded 26°C without any buckles occurring, whilst the greatest number of buckles ever recorded on one day occurred on 10th June 1969 when the maximum temperature was only just over 23°C. The one common feature that stands out from all the graphs is that significant numbers of distortions have always been preceded by a large rise in the daily maximum temperature and, perhaps more significantly, in the difference between day and night temperatures. In most cases the temperature rise was from around or below 15°C to approaching or exceeding 25°C with a corresponding increase in the difference between day maximum and night minimum temperatures. I think it very probable that this pattern of a large temperature rise, concentrated over a few days, is the particular feature that led to the sharp increase in the number of distortions during 1969: it is the only significant meteorological factor which distinguishes 1969 from previous years and its effect on the track, especially on the interaction between sleepers and ballast, must in my opinion have been decisive in those cases where other effects had reduced the safety margins against buckling to nearly zero.

CONCLUSIONS AND RECOMMENDATIONS

60. My Inquiry was concerned first with the derailment of trains on CWR track at Lichfield, Somerton, and Sandy. All three derailments were caused by the heat distortion of the CWR track, and my findings on each individual accident appears under the appropriate heading in the body of this report. In brief, these show that a convincing explanation can be given for the distortion at Somerton but that, mainly because of the lack of reliable evidence concerning the stress conditions in the track immediately before distortion, the conclusions on the other two accidents must be to some extent conjectural.

61. The extension of my terms of reference to include the general safety of CWR track as installed on British Railways considerably widened the scope of my Inquiry and the Conclusions that follow are concerned solely with this wider aspect. Some of the remarks I make have already appeared in the interim report but I include them here so that these Conclusions may be complete in themselves.

62. British Railways adopted continuous welded rail track as a standard in 1959 following lengthy technical investigations, and at a time when such track was already in use on many other railways. The form of track adopted was necessarily designed for the national temperature range and the humid and generally corrosive atmosphere to be found in Britain. The advantages to be gained from the use of CWR made its adoption almost inevitable once its practicability was established. Apart from the quieter and more comfortable ride for passengers these advantages included economic ones, such as an extension of rail life between 30 and 40 per cent, savings in the cost of track maintenance, extended sleeper life, and reduction in fuel costs and wear and tear on rolling stock, as well as the important gain in safety resulting from the elimination of rail joints. The latter have always been the weakest point in conventional jointed track and by far the greatest number of rail breaks, and those potentially the most dangerous, have been associated with the fishbolt holes at rail ends. It will be recalled that the derailment of a passenger train at Hither Green (Southern Region) in November 1967, in which 49 people were killed, resulted from a rail break at a joint in conventional jointed track.

63. Experience between 1959 and 1968, during which period the mileage of CWR track grew from 200 to nearly 4,000 miles, seemed to show that the track design and the specification for laying and maintaining it were sound. The annual rate of distortions was small and constant: many more distortions occurred each year on the old jointed type of track in spite of the provision for heat expansion which this form of track provides. Even the two derailments that occurred on CWR track during 1968 could perhaps be regarded as special cases. In each the track buckled actually under the train, in each the train was a freightliner and in each some element of human error was present. However, the events of the summer of 1969 indicated, firstly, that the factor of safety against buckling with the track subject to high thermal compression was insufficient and, secondly, that the old practices for the installation and maintenance of CWR track and the interpretation and application of these to work on the ground left something to be desired.

64. Once these facts came to light it was clear that the first priority had to be to ensure that existing lines laid with CWR would be safe for traffic before the onset of warm weather in 1970. In paragraph 65 of the interim report I detailed the steps that the Railways Board then took, and paragraphs 42 and 43 of the present report show how this work has developed and continued.

65. The success of these measures is clearly shown by Table 1 in this report. Since 1970, proportionally fewer distortions have occurred in CWR track than at any time before, and the only accident to occur as a result of distorted CWR resulted from a failure to maintain the track to the required standards. Moreover, many of the distortions that have occurred in CWR since 1970 have been in track that was already under surveillance or subject to a precautionary speed restriction so that the risk of accident was also less. In contrast, a number of accidents have occurred since 1970 on heat-distorted *jointed* track, including the serious derailment of a school's excursion train at Tattenhall Junction in July 1971 in which two children lost their lives.* It is also significant that whilst the patterns of temperature variation were unexceptional during the years 1970–1972 this was not the case during 1973. Sharp rises in day temperature and in the difference between maximum day temperature and minimum night temperature, on a par with those associated with the serious CWR distortions of 1969 occurred on two or three occasions during the summer of 1973 and whilst some distortions were reported the numbers were small. This shows that the strengthened track now has a factor of safety sufficient to cope with these testing meteorological conditions.

66. Currently with the practical measures taken by the Board to increase the stability of the existing CWR track, and the revision of the standards for laying and maintaining track in the future, the Board initiated a comprehensive programme of investigation and research. The details given in this report show that much has been achieved, but certain questions are still unanswered or the answers imperfectly understood. In particular, the effect of dynamic loadings on the track, both vertical and lateral, and their significance in the development of small initial misalignments needs further study, as does the exact significance of cyclic variations in ambient temperature and of the effects thought to be due to the rolling out of rails. Work on these and many other aspects of CWR is of course continuing and I recommend that it continues to receive an appropriate priority so that the behaviour of CWR under *any* conditions likely to be met in practice can be predicted with even greater certainty than is possible at present.

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*This accident was the subject of a public Inquiry and the Report on it was published in May 1972.

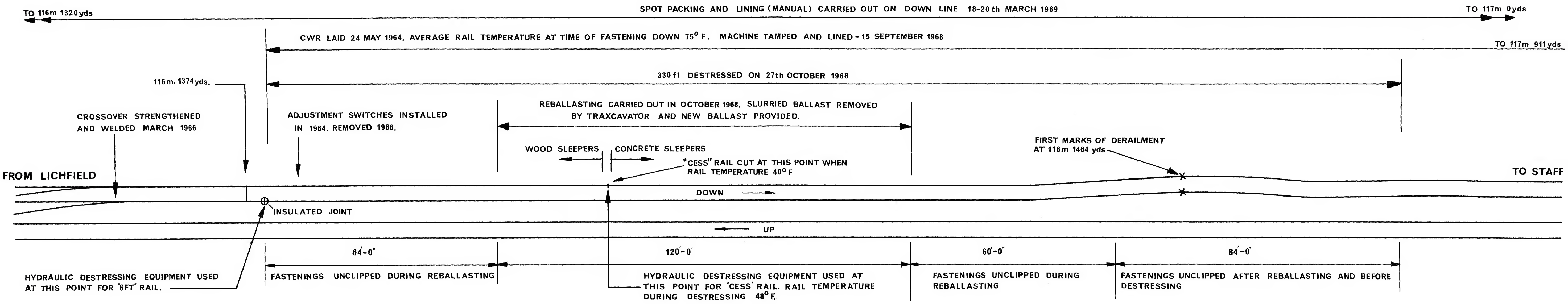
67. CWR is a logical development of traditional jointed track and it has important advantages in terms of safety as well as economy when compared with the older forms of track. Practical experience extending over many years, supported by theoretical and practical research, has shown that its stability against heat distortion can be as great as, or greater than, that of jointed track under any combination of traffic and environmental conditions to be found on British Railways. For the high speeds now used, and the higher speeds contemplated, its use is essential. Its stability, however, depends absolutely on the care with which it is laid and thereafter maintained. Provided it is laid and maintained in strict conformity with the Board's current code of practice it will be safe: if these standards are not met it may become potentially or actually unstable under certain meteorological conditions. Experience since 1970 has shown that by and large the new standards are being met and maintained, although the continued occurrence of even a few distortions and the circumstances of the accident at Cumbernauld show that vigilance cannot and must not be relaxed.

68. Although CWR is currently the most satisfactory form of track for modern high speed railways it is at best a compromise. The elimination of the weakest feature of previous forms of track, the joint between short lengths of rail, brought with it the need to contain within the track structure stresses and strains quite unconnected with the loads brought to bear by the traffic that the track was designed to carry. Whilst rail steels continue to possess a significant co-efficient of thermal expansion the problem will remain. There seems little prospect that future rail steels will have lower co-efficients than those at present in use: indeed it seems likely that some new steels being developed may even have increased co-efficients. World trends are also towards heavier axle-loads and consequently heavier rails, and since the force locked inside a rail is proportional to its cross-sectional area for a given temperature rise, this may also tend to aggravate the situation. There are of course ways, not necessarily economic, by which the lateral stability of CWR track can be increased still further. The interval between sleepers, for example, can be decreased by providing more sleepers in a given length, and the logical extension of this concept is the use of a continuous solid support for the rails instead of the sleeper-ballast structure normally employed. Various forms of slab track are being developed in many parts of the world, not least in Britain, and so far as stability is concerned it would seem to offer an almost complete solution since lateral buckling of such track is all but impossible. The use of slab track in the future will depend of course on economic and operational as well as technical factors but I recommend that when and if such factors come to be weighed in respect of future track on British Railways, and I am thinking here particularly of future very high speed lines, the greater guarantee of safety that can be given with a continuously supported track be given due consideration.

I have the honour to be,
Sir,
Your Obedient Servant,
C. F. ROSE,
Major.

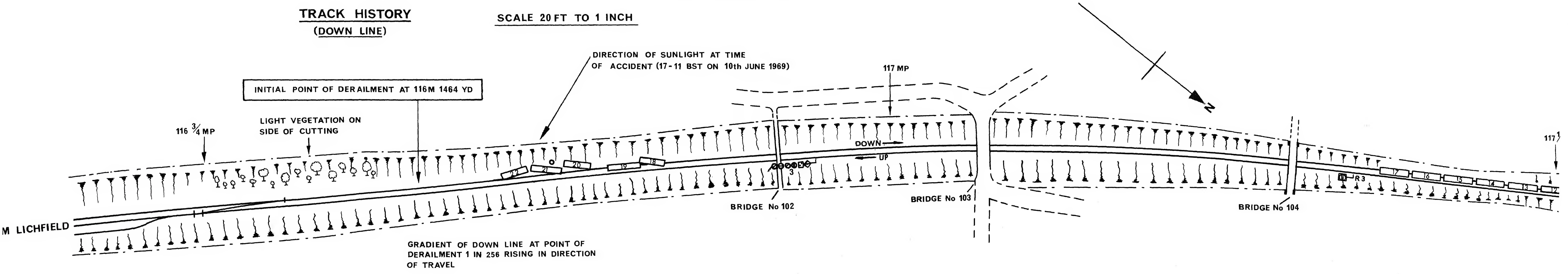
The Permanent Secretary,
Department of the Environment

DERAILMENT AT LICHFIELD (L.M. REGION) 10 th JUNE 1969


TO 116m 1320 yds
SPOT PACKING AND LINING (MANUAL) CARRIED OUT ON DOWN LINE 18-20 th MARCH 1969
TO 117m 0 yds
CWR LAID 24 MAY 1964. AVERAGE RAIL TEMPERATURE AT TIME OF FASTENING DOWN 75° F. MACHINE TAMPED AND LINED - 15 SEPTEMBER 1968
TO 117m 911 yds
116m. 1374 yds.
330 ft DESTRESSED ON 27th OCTOBER 1968
CROSSOVER STRENGTHENED AND WELDED MARCH 1966
ADJUSTMENT SWITCHES INSTALLED IN 1964. REMOVED 1966.
REBALLASTING CARRIED OUT IN OCTOBER 1968. SLURRIED BALLAST REMOVED BY TRAXCAVATOR AND NEW BALLAST PROVIDED.
WOOD SLEEPERS
CONCRETE SLEEPERS
"CESS" RAIL CUT AT THIS POINT WHEN RAIL TEMPERATURE 40° F
FIRST MARKS OF DERAILMENT AT 116m 1464 yds
FROM LICHFIELD
TO STAFF
DOWN
INSULATED JOINT
UP
64'-0"
120'-0"
60'-0"
84'-0"
HYDRAULIC DESTRESSING EQUIPMENT USED AT THIS POINT FOR '6FT' RAIL.
FASTENINGS UNCLIPPED DURING REBALLASTING
HYDRAULIC DESTRESSING EQUIPMENT USED AT THIS POINT FOR 'CESS' RAIL. RAIL TEMPERATURE DURING DESTRESSING 48° F.
FASTENINGS UNCLIPPED DURING REBALLASTING
FASTENINGS UNCLIPPED AFTER REBALLASTING AND BEFORE DESTRESSING

TRACK HISTORY
(DOWN LINE)

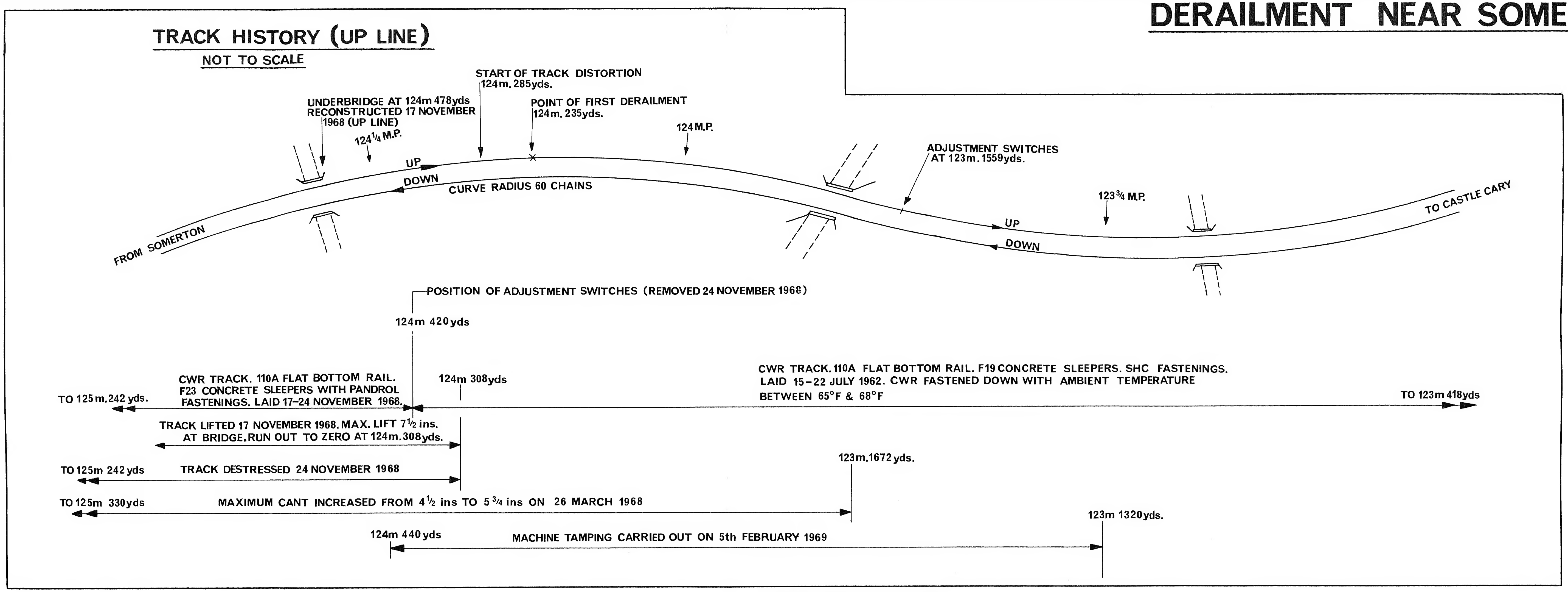
SCALE 20 FT TO 1 INCH

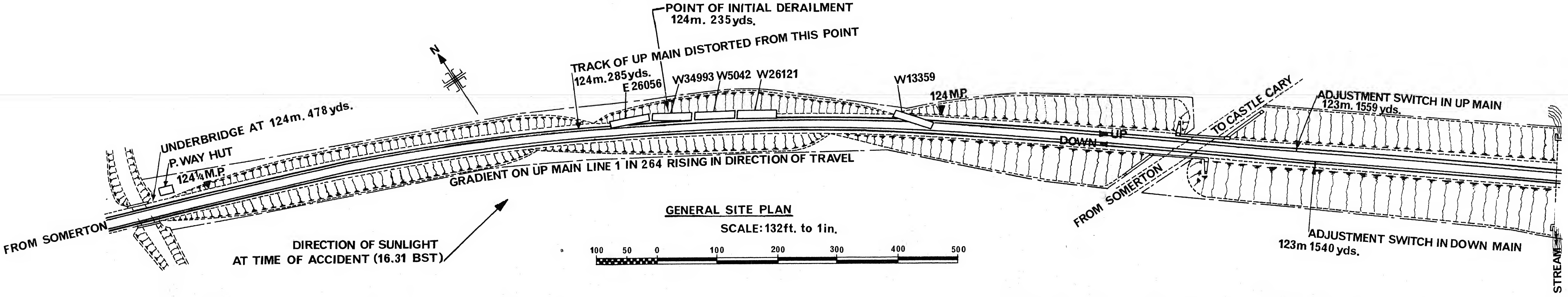

N
DIRECTION OF SUNLIGHT AT TIME OF ACCIDENT (17-11 BST ON 10th JUNE 1969)
117 MP
INITIAL POINT OF DERAILMENT AT 116M 1464 YD
LIGHT VEGETATION ON SIDE OF CUTTING
116 ¾ MP
DOWN
UP
22
21
20
19
18
3
17
16
15
14
13
12
R 3
117 1/
M LICHFIELD
BRIDGE No 102
BRIDGE No 103
BRIDGE No 104
GRADIENT OF DOWN LINE AT POINT OF DERAILMENT 1 IN 256 RISING IN DIRECTION OF TRAVEL

SITE PLAN SHOWING INITIAL POINT OF DERAILMENT AND POSITION IN WHICH TRAIN CAME TO REST

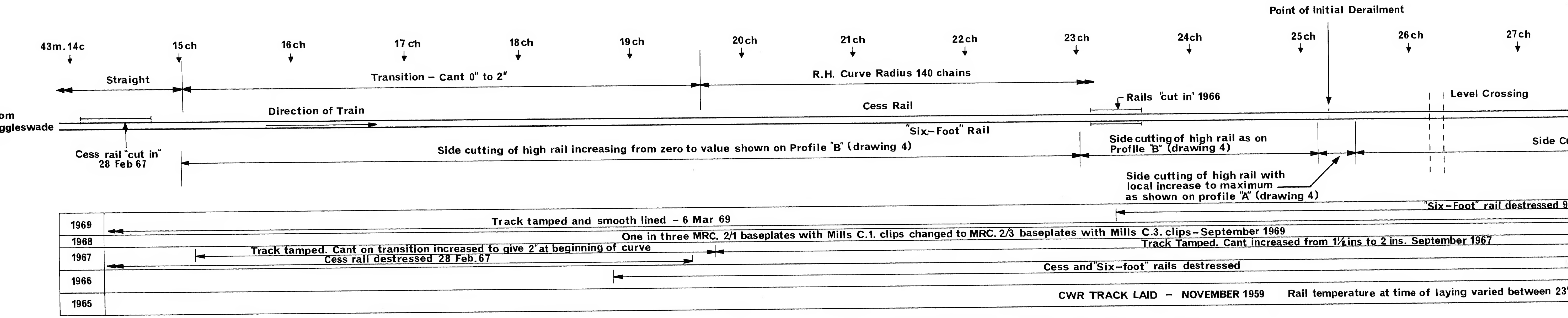
SCALE—132 FT TO ONE INCH

DERAILMENT NEAR SOMERT

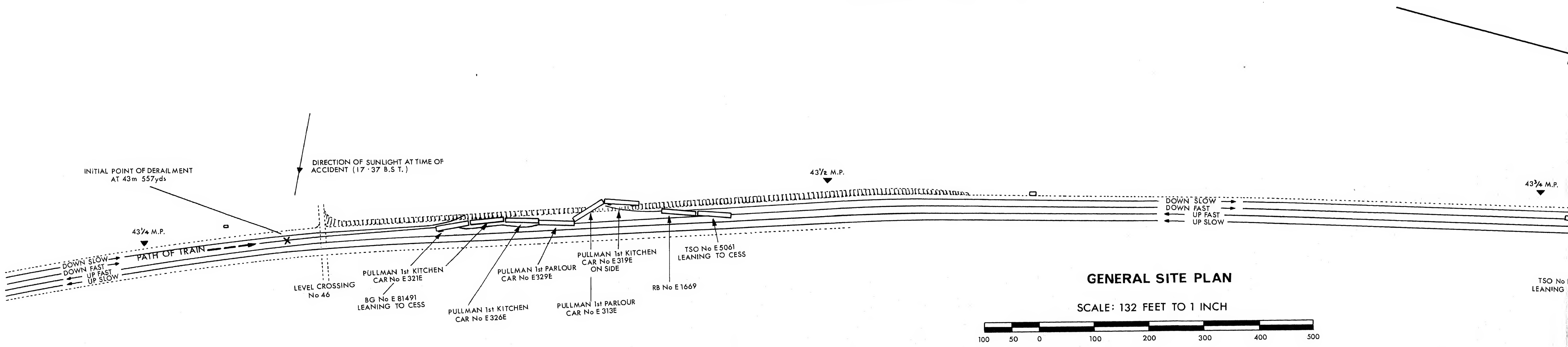

TRACK HISTORY (UP LINE)
NOT TO SCALE
START OF TRACK DISTORTION 124m. 285yds.
UNDERBRIDGE AT 124m 478yds RECONSTRUCTED 17 NOVEMBER 1968 (UP LINE)
POINT OF FIRST DERAILMENT 124m. 235yds.
124 M.P.
124¼ M.P.
UP
DOWN
CURVE RADIUS 60 CHAINS
ADJUSTMENT SWITCHES AT 123m. 1559yds.
123¾ M.P.
TO CASTLE CARY
FROM SOMERTON
UP
DOWN
POSITION OF ADJUSTMENT SWITCHES (REMOVED 24 NOVEMBER 1968)
124m 420yds
CWR TRACK. 110A FLAT BOTTOM RAIL. F23 CONCRETE SLEEPERS WITH PANDROL FASTENINGS. LAID 17-24 NOVEMBER 1968.
124m 308yds
CWR TRACK. 110A FLAT BOTTOM RAIL. F19 CONCRETE SLEEPERS. SHC FASTENINGS. LAID 15-22 JULY 1962. CWR FASTENED DOWN WITH AMBIENT TEMPERATURE BETWEEN 65°F & 68°F
TO 125m.242 yds.
TO 123m 418yds
TRACK LIFTED 17 NOVEMBER 1968. MAX. LIFT 7½ ins. AT BRIDGE. RUN OUT TO ZERO AT 124m.308yds.
123m.1672 yds.
TO 125m 242 yds
TRACK DESTRESSED 24 NOVEMBER 1968
TO 125m 330yds
MAXIMUM CANT INCREASED FROM 4½ ins TO 5¾ ins ON 26 MARCH 1968
123m 1320yds.
124m 440 yds
MACHINE TAMPING CARRIED OUT ON 5th FEBRUARY 1969


POINT OF INITIAL DERAILMENT 124m. 235yds.
TRACK OF UP MAIN DISTORTED FROM THIS POINT 124m. 285yds.
N
E 26056
W34993
W5042
W26121
W13359
124 M.P.
UNDERBRIDGE AT 124m. 478 yds.
P. WAY HUT
124¼ M.P.
TO CASTLE CARY
ADJUSTMENT SWITCH IN UP MAIN 123m. 1559 yds.
DOWN
UP
GRADIENT ON UP MAIN LINE 1 IN 264 RISING IN DIRECTION OF TRAVEL
FROM SOMERTON
FROM SOMERTON
DIRECTION OF SUNLIGHT AT TIME OF ACCIDENT (16.31 BST)
GENERAL SITE PLAN
SCALE: 132ft. to 1in.
100 50 0 100 200 300 400 500
ADJUSTMENT SWITCH IN DOWN MAIN 123m 1540 yds.
STREAM

DERAILMENT AT SANDY (E. REGION) – 23 JULY 1969


Point of Initial Derailment
43m. 14c
15 ch
16 ch
17 ch
18 ch
19 ch
20 ch
21 ch
22 ch
23 ch
24 ch
25 ch
26 ch
27 ch
Straight
Transition – Cant 0" to 2"
R.H. Curve Radius 140 chains
Rails "cut in" 1966
Level Crossing
om
ggleswade
Direction of Train
Cess Rail
"Six-Foot" Rail
Cess rail "cut in" 28 Feb 67
Side cutting of high rail increasing from zero to value shown on Profile "B" (drawing 4)
Side cutting of high rail as on Profile "B" (drawing 4)
Side C
Side cutting of high rail with local increase to maximum as shown on profile "A" (drawing 4)
1969
1968
1967
1966
1965
"Six-Foot" rail destressed 9
Track tamped and smooth lined – 6 Mar 69
One in three MRC. 2/1 baseplates with Mills C.1. clips changed to MRC. 2/3 baseplates with Mills C.3. clips – September 1969
Track Tamped. Cant increased from 1½ ins to 2 ins. September 1967
Track tamped. Cant on transition increased to give 2" at beginning of curve
Cess rail destressed 28 Feb. 67
Cess and "Six-foot" rails destressed
CWR TRACK LAID – NOVEMBER 1959
Rail temperature at time of laying varied between 23

TRACK HISTORY DOWN FAST LINE Scale 40 ft to 1in


INITIAL POINT OF DERAILMENT AT 43m 557yds
DIRECTION OF SUNLIGHT AT TIME OF ACCIDENT (17·37 B.S.T.)
43¼ M.P.
PATH OF TRAIN
DOWN SLOW
DOWN FAST
UP FAST
UP SLOW
LEVEL CROSSING No 46
PULLMAN 1st KITCHEN CAR No E321E
BG No E 81491 LEANING TO CESS
PULLMAN 1st KITCHEN CAR No E326E
PULLMAN 1st PARLOUR CAR No E329E
PULLMAN 1st KITCHEN CAR No E319E ON SIDE
PULLMAN 1st PARLOUR CAR No E 313E
RB No E 1669
TSO No E 5061 LEANING TO CESS
43½ M.P.
43¾ M.P.
TSO No
LEANING
100
50
0
100
200
300
400
500

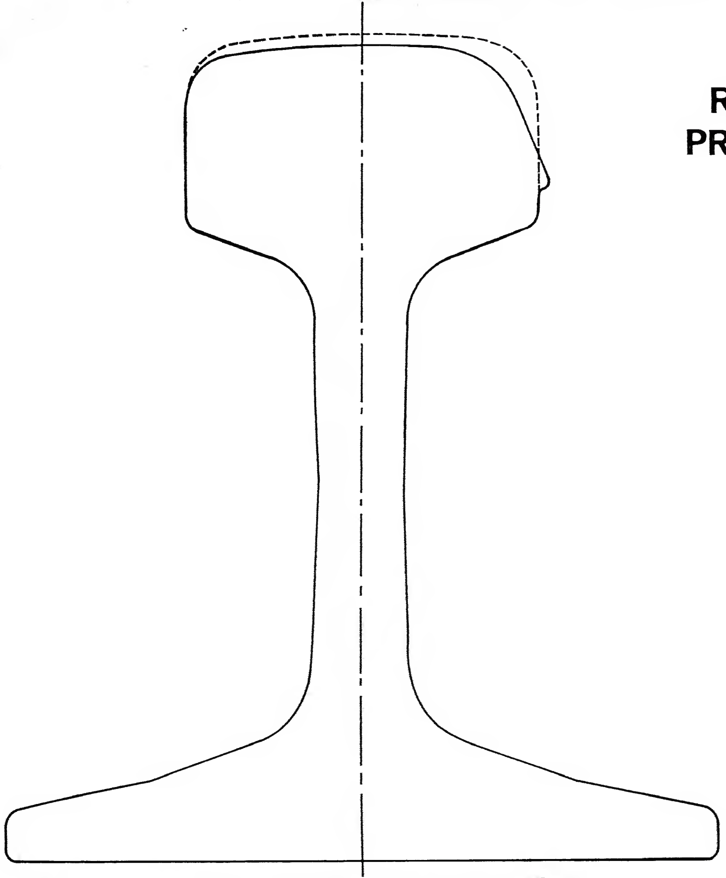
GENERAL SITE PLAN

SCALE: 132 FEET TO 1 INCH

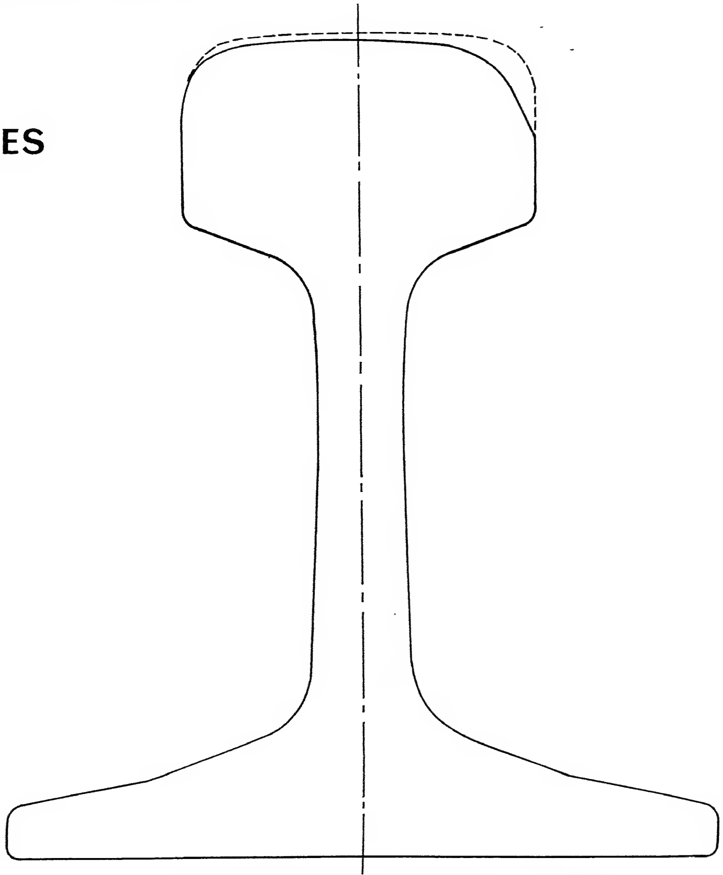
DRAWING 4.

DERAILMENT AT SANDY (E. REGION) —23rd JULY, 1969.

RAIL PROFILES



CESS RAIL PROFILE "A"
IN IMMEDIATE VICINITY OF DERAILMENT



CESS RAIL PROFILE "B"
SOUTH OF POINT OF DERAILMENT

SCALE: FULL SIZE

MINISTRY OF TRANSPORT

RAILWAY ACCIDENTS

Interim Report

on the Derailments that occurred
on Continuous Welded Rail Track
at Lichfield (London Midland Region),
Somerton (Western Region),
and Sandy (Eastern Region),
British Railways, during June and July 1969
and on the General Safety of this form of Track

UNIVERSITY OF CAMBRIDGE
8 M
1970

LONDON: HER MAJESTY'S STATIONERY OFFICE
1970

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MINISTRY OF TRANSPORT,
ST. CHRISTOPHER HOUSE,
SOUTHWARK STREET,
LONDON, S.E.1.

16th February 1970.

INTERIM REPORT ON THE DERAILMENTS THAT OCCURRED ON CONTINUOUS WELDED RAIL TRACK AT LICHFIELD (L.M. REGION), SOMERTON (W. REGION) AND SANDY (E. REGION) DURING JUNE AND JULY 1969, AND ON THE GENERAL SAFETY OF THIS FORM OF TRACK

SIR,

1. I have the honour to present for the information of the Minister of Transport, in accordance with the Order dated 17th June 1969, an interim report on my Inquiry into the derailment of an express passenger train near Somerton in the Western Region of British Railways on 13th June 1969. The terms of reference of this Inquiry were extended, by amendments to the Order dated 14th July 1969 and 24th July 1969 to include the derailment, on 10th June 1969, of an empty car-flat train at Lichfield in the London Midland Region, the derailment of a passenger express train near Sandy in the Eastern Region on 23rd July 1969, and also the general question of the safety of track formed of continuous welded rails. This interim report will, therefore, include an analysis of failures in continuous welded rail (CWR) track during 1969 and an account of investigations being made into its general stability, as well as the result of enquiries made to date into the three train accidents. Only such detail will be included as is necessary to make any conclusions reached readily understood. A full report covering all other matters relevant to the accidents and the results of current research into the design, laying, and maintenance of CWR track will be presented later.

2. Two main factors have prompted the presentation of an interim report. First, the general public concern, expressed in Parliament and the press, following the accidents caused by buckling of CWR track in the summer of 1969, and secondly the length of time that would necessarily elapse before a complete report could be made. Some of the experimental work designed to establish the full reasons for the sudden increase in the number of distortions in CWR that occurred in 1969 will not be complete until late in 1970 or early in 1971, and it is thought that an account of the work now in hand, and the measures already being taken to avoid a recurrence of the high failure rate of 1969 should be published before the onset of the hot weather in 1970.

BACKGROUND

3. Comment made after the train accidents which form the subject of this report often referred to CWR track as "new", "unconventional" or "experimental". In fact such track has been in general use on most of the major railways of the world for more than twenty years. The present mileage of welded rail track in Europe alone exceeds 60,000 miles. British Railways adopted its use relatively late, and it is only since about 1959 that it has been laid extensively in this country. The present length on British Railways is approximately 4,600 track miles. Germany has over 27,000 miles and France over 7,000 miles.

4. Theoretical studies of the stability of CWR track were first made, in Europe, between 1913 and 1918, and the first welded lengths were in service both on the continent and in America by the early 1930s. In 1937 the London Midland and Scottish Railway welded together a 2,213 ft length of track for experimental purposes on a closed branch line, and at about the same time the London Passenger Transport Board initiated programmes of experimental work on jointless track. In 1950 the Control Committee of the Office for Research and Experiments (ORE) of the International Union of Railways (UIC) reviewed current designs and practices in different member countries, and initiated a concerted programme of study and research into CWR track. Important parts of this programme were carried out in Great Britain by the British Transport Commission, and the results of these were published in 1961 under the title "Experiments on the Stability of Long Welded Rails". Results of the international programme of research were published in April 1965 by the UIC under the title "Lateral Stability of Rails, especially of Long Welded Rails".

5. Following the decision to install CWR track on main lines in this country, a Code of Practice was issued by the British Transport Commission in May 1962. This was Civil Engineering Handbook No. 11 "General Instructions for the Installation and Maintenance of Continuous Welded Flat Bottom Track". With amendment, and the issue of Supplements to cover the use of hydraulic destressing equipment, this Handbook was until very recently the standard reference for all work on CWR track on British Railways. Early experience indicated that the careful specification for laying and maintaining CWR track, contained in Handbook No. 11 and representing the results of considerable research and development, was generally satisfactory. The following Table shows the pattern of distortion in both CWR and jointed track from 1958 to 1969:

TRACK DISTORTIONS ON BRITISH RAILWAYS 1958–69

Year	Track Mileage Jointed Track	Track Mileage CWR Track	Distortions on Jointed track	Distortions on CWR track	Distortions per 1,000 miles per annum	
					Jointed	CWR
1958	33,953	117	6	1	0·18	—
1959	33,335	201	48	6	1·44	—
1960	33,076	343	15	Nil	0·45	—
1961	32,308	664	24	2	0·74	—
1962	31,300	1,025	18	3	0·58	2·93
1963	30,258	1,392	33	6	1·09	4·32
1964	28,555	1,791	19	3	0·67	1·67
1965	26,450	2,346	18	2	0·68	0·85
1966	23,953	2,885	22	5	0·92	1·73
1967	22,345	3,387	27	6	1·21	1·77
1968	20,480	3,939	22	7	1·07	1·78
1969	18,490	4,605	55	48	2·98	10·42

NOTE: The mileage of CWR track includes continuous welded serviceable rail track (approx. 600 miles).

6. The track distortions on CWR lines listed above caused no serious accidents until the summer o 1968, when two Freightliner trains were derailed; one at Berkhamsted (London Midland Region) and the other at Auchencastle (Scottish Region). The first of these two accidents was the subject of a public Inquiry, with which the second accident was associated, and the Report by Colonel W. P. Reed on these two derailments was published in October 1969.

ANALYSIS OF CWR TRACK DISTORTIONS—1969

7. In conjunction with the British Railways Board a detailed analysis has been made of the CWR distortions that occurred during the summer of 1969. Details of the track, its laying and maintenance history, meteorological conditions at the time of buckling, and other relevant information have been listed for each distortion, together with the results of investigations carried out by the staff of the Chief Civil Engineers of the Regions concerned. The main points arising from this analysis are as follows:—

(*a*) In 17 of the 48 cases (35 per cent) consolidation of the ballast was unsatisfactory and voids were present below the sleepers. Although in a few cases this could be attributed to poor maintenance the majority resulted from work previously carried out on the track. When ballast is disturbed, for example during lining or packing, full consolidation is not achieved until the track has carried traffic for some time, unless special measures are taken to speed the compaction (in this connection see para. 65*h*).

(*b*) In 13 of the 48 cases (27 per cent) distortion could be attributed in whole or in part to failure to carry out the provisions of Handbook No. 11. These included failing to destress track after laying, shortage of ballast, and allowing work to be carried out on the track when rail tempertures were above the maximum permitted for such work.

(*c*) Of the remaining 18 cases, 11 were associated with discontinuities of some form in the welded track, such as catch points, insulated joints, and ordinary points and crossings. Such interruptions in the continuous track are always a potential point of weakness and this is recognised by the issue of special instructions for their maintenance. Two other cases were traced to colliery subsidence which had affected the whole track formation and would probably have caused distortion irrespective of the type of track.

(*d*) Although a definite cause could be found for nearly all the distortions it was also obvious that in a significant number the factor of safety against lateral instability must have been considerably lower than that predicted by the current, well established, methods of calculation. The possible reasons for this, and the work currently in hand to investigate this aspect of the problem are discussed later in the report.

(*e*) The incidence of distortions was greatest in two relatively concentrated periods. The first was between the 7th and the 15th June, when 17 distortions were reported and the second between the 12th and 16th July, when a further 16 were reported. Outside these two periods distortions occurred at intervals, from early May until the beginning of September, with seldom more than one distortion being reported on any given day.

(*f*) All 48 distortions occurred during the afternoon and early evening, and 40 of them (83 per cent) occurred between 14.00 and 18.00 with a peak (10 cases) between 14.30 and 15.00. The earliest recorded distortion was at 13.30, and the latest (an isolated case) at 20.08. All times are British Standard Time.

(*g*) Distortions were reported in all Regions of British Railways but the greatest number were located in an area that included the Midlands, the western parts of East Anglia and the Liverpool–Manchester–Leeds areas. Relatively few occurred in Western, Southern and Scottish Regions.

(*h*) Information provided by the Meteorological Office showed that maximum temperatures and hours of sunshine were not significantly higher during June and July 1969 than in previous years. Peak temperatures in fact were generally lower than in 1968. However, during June and July 1969 there were many clear nights and early mornings when ground temperatures were very low; the difference between these early morning ground level temperatures and maximum day air temperatures was often as much as 40°F, and the difference between maximum and minimum rail temperatures could well have been 80° or more.

(*i*) Three train accidents were directly caused by the buckling of CWR track ahead of the train and are the accidents examined in this Report:

10th June — Derailment of an empty carflat train at Lichfield, L.M. Region.

13th June — Derailment of a Paignton–Paddington express passenger train near Somerton, W. Region.

23rd July — Derailment of the Tees–Tyne Pullman passenger express at Sandy, E. Region.

(*j*) One train accident was directly caused by CWR track buckling under the train:

15th July — Derailment of a freightliner train at Lamington, Scottish Region.

(*k*) In addition to these four accidents the derailment of a Freightliner train, also on 15th July, at Granthouse, Scottish Region, may have been caused by CWR track buckling under the train but in this case other factors were present and the buckling might have been the effect rather than the cause of derailment. Inquiries into this accident by British Railways and Freightliners Ltd are continuing.

TRAIN ACCIDENTS

Lichfield

8. At approximately 17.11 on 10th June 1969 in exceptionally fine hot weather, the 11.15 Dagenham to Garston empty car ferry train was derailed on straight track in a cutting approximately half a mile north of Lichfield Station on the West Coast Main line, London Midland Region. The train consisted of 22 empty carflats hauled by a Class 86 AL6 electric locomotive. The train weighed a total of 624 tons, and its authorised maximum speed was 75 m.p.h. The carflat vehicles were all converted passenger stock.

9. Derailment probably commenced with the 10th vehicle. The 9th to 17th vehicles inclusive became derailed and a division occurred between the 17th and 18th vehicles. The 18th to 22nd vehicles, also derailed, came to rest about 500 yards in rear of the leading part of the train. Damage was heavy to a number of the derailed vehicles and the last five in the train had to be cut up before the lines could be cleared. Both Up an Down lines were blocked and extensive damage was done to the permanent way and to the overhead line equipment. At the point where derailment had first occurred the track was distorted over a length of more than 100 ft, the maximum misalignment being between 2 ft 6 ins and 3 ft. The train crew protected both lines in accordance with the Rules. No train was approaching on the Up line at the time of the accident.

10. No one was injured. The breakdown services were ordered at 17.15 and all lines were cleared late on 11th June. Extensive delays and cancellations resulted from the accident.

11. The train crew consisted of four men. The driver, secondman and an experienced driver learning the route occupied the leading cab of the locomotive and the guard was travelling in the rear cab. Entering the cutting north of Lichfield, with the train travelling at about 60 m.p.h., the driver was glancing at his instruments, the secondman had just left his seat to heat some coffee, and the route-learning driver was moving into the secondman's seat. Of the three men only the route-learning driver was thus looking at the track ahead and he saw a distortion in the line which he described as buckled $\frac{1}{2}$ inch to 1 inch towards the cess. He saw this just before the locomotive passed over it and then felt a jolt as though the engine was passing through points. He shouted a warning to the train driver, but the latter did not hear, possibly because the cab windows were both open and the noise level was high. At this moment the brakes began to come on and the guard hurried in to say that something had occurred towards the rear of the train. The driver shut off power and brought the front part of the train to a halt.

12. Although it was impossible to judge with any certainty the state of the derailed vehicles immediately before the accident, subsequent detailed examination failed to reveal anything in the condition of the train that could have caused or contributed to the derailment.

13. The Down line in the cutting at the point of derailment was formed of 110 lb per yard flat bottom continuous welded rail on concrete sleepers with SHC fastenings. Ballast was 1½ in. nominal granite with a 12–14 in. shoulder on the cess side, well filled cribs, and 12 ins depth under the sleepers. The CWR track had been laid in May 1964 when the rail temperature was approximately 75°F. In 1966 a trailing crossover situated with the toe of the switches 270 feet on the Lichfield side of the point of derailment was relayed in strengthened and welded point and crossing work, and on this occasion a set of adjustment switches, laid adjacent to the switches in the Down line, was removed and plain line substituted. From the toe of the switches the first 105 feet of track towards the point of derailment was on timber sleepers. Drawing 1 at the end of this report shows the salient details. Maximum line speed was 100 m.p.h. but on the straight track where derailment occurred there was a permanent speed restriction of 90 m.p.h. The gradient is 1 in 256 rising.

14. In October 1968, 120 feet of the Down line between the crossover and the point of derailment was found to be slurried. The track was released from its fastenings over a length of 244 feet, the six-foot rail was released at an insulated joint at the switches, the cess rail cut, and both rails were moved out into the cess and six-foot way. The ballast was then removed by traxcavator. At the time of cutting, rail temperature was measured at 40°F, and calculations showed that the stressing of the rails before cutting was equivalent to a stress-free rail temperature of 75°F. After completion of the reballasting the rails were placed on nylon slides, a further 84 feet of fastenings were released (making 330 feet in total from the crossover switches) and the track stressed by hydraulic equipment to an equivalent rail temperature of 75°F. No datum points were established beyond the unfastened length to check on possible movement of the track that was being used as an anchorage. The insulated joint was then remade, and the cess rail re-welded after the correct welding gap had been made by burning. Rail temperature at this time was 48°F.

15. In March 1969 measured shovel packing and manual lining was carried out along the length that had been reballasted. No further work was done on the track until the derailment.

16. During the afternoon of 10th June, the day of the accident, shade temperatures recorded at Birmingham Airport (16 miles from Lichfield) were 21·3°C (80°F) at 16.00 and 21·0°C (79°F) at 17.00 with a maximum temperature for the day of 21·6°C (81°F). There was very little cloud during the afternoon, and the wind was from the north-east, light to moderate.

17. A Leading Trackman responsible for inspection of the length walked along the Down line in the area concerned at about 15.30. He saw nothing wrong with the track. In view of the hot weather he planned to carry out a further inspection of the track in the cutting between 17.30 and 18.00 (under Rule 221(e) which requires additional inspection in exceptional weather conditions) but by then the derailment had taken place.

18. The last train to pass over the Down line before the 11.15 car-ferry train was the 12.00 hrs Garston to Maidenhead car-ferry train, composed of 19 loaded carflats. It passed through Lichfield at 16.52, i.e. 19 minutes before the accident. This train had been wrongly routed at Stafford in the Up direction and was returning from Nuneaton over the Down line to take up its correct route. The train crew noticed nothing unusual in the track or the train ride as they went through the cutting north of Lichfield Station.

19. Taking into account the evidence of the driver who saw the buckled track, the course of the derailment, the condition of the track after the derailment, and the high temperature obtaining at the time, I am satisfied that the direct cause of the accident was a distortion in the CWR track. It seems most probable that a small but noticeable heat induced buckle appeared after the passage of the 12.00 car-ferry train at 16.52, that this developed into a much larger distortion as the locomotive and leading vehicles of the 11.15 car-ferry train passed over it, and that derailment of the 10th and following vehicles of this train resulted.

20. Despite a very detailed examination of the track data and many tests it cannot be said at present that a clear explanation for the buckling of the track in this case has been found. Several factors have been identified, none of which on its own would fully explain the failure, but which in combination might have produced a situation in which buckling could occur. These factors can be summarised as follows:

(*a*) When the track was first laid, in 1964, it was not the general practice to raise the rail onto rollers or slides when destressing, and rollers were not used on this occasion. Although records show that the rail was fastened down whilst the average rail temperature was 75°F there is no guarantee that the entire length was stress free at this temperature; indeed, experience gained since 1964 would suggest that the stress variation under the conditions in which the rail was laid might have been considerable.

(*b*) During the ballast changing in October 1968, the Technical Assistant in charge calculated the equivalent stress-free temperature as 75°F after he had released the continuous rail. However, these calculations depend on very accurate measurement of the rail gap after freeing: an error of only 0·2 ins would represent a temperature difference of about 10°F over the length involved in this case. Any lowering of the equivalent stress-free temperature (such as has been found in many places elsewhere: see para 63) might possibly have passed unnoticed and the subsequent stressing have merely restored the track to its previous condition. That this happened is, of course, pure conjecture, and it is unlikely that an experienced Assistant would make such a mistake, but had he done so this would have provided a further factor tending to lower the safety margin.

(*c*) When the track was opened out for reballasting in October 1968, the rails were disconnected as described in para 14 and moved into the cess and six-foot ways. It is possible that in slewing the rails, (particularly the cess rail which was moved outwards and downwards to rest in the cess some three feet below its original level), a stress approaching or even passing the yield point might have been induced accidentally. This would not necessarily have been detectable when the rails were replaced but might have left a weak point in the rails very close to the point where buckling eventually occurred. Tests are being made to check the stresses induced in rails that have been subjected to bending and twisting in this manner.

(*d*) The October 1968 reballasting was necessary because of slurried ballast. There was thus, at that time, evidence that the formation was not altogether satisfactory. Nothing, however, suggested subsequently that the formation was in poor condition, since the reports from those responsible for track maintenance and the results of track recording machine runs, the last of which was carried out on 21st May 1969, showed the track to be in good condition. Nevertheless, the possibility that some slight movement or settlement in the formation had taken place, leading to distorted track or the presence of voids, cannot be ruled out.

(*e*) Examination of the rails removed from the track in the area of the buckle showed a uniform side cutting on both cess and six-foot rails towards the top of the rail head. This, on straight track, would suggest some degree of lateral thrust on the track from the wheels of vehicles.

(*f*) Shortly before the accident the sun would have been at an angle of about 55° to the direction of the track in the cutting, and at an elevation of approximately 36°. Stress differences across the section of a rail of as much as 0·95 tons per square inch have been measured experimentally when the sun's radiation has been incident on one side only, as in this case. This stress results in a lateral force, not in itself dangerous, but definitely causing a small decrease in the safety factor against lateral buckling.

(*g*) At the point where the distortion first commenced the track was in direct sunshine. A few yards to the south, light vegetation on the banks of the cutting produced shade on the line, and some variation in rail temperature would thus be probable.

(*h*) There is finally the fact that destressing should perhaps have extended at least 300 ft beyond the point at which the rails were unfastened, with datum points established so that any movement occurring beyond the limit of destressing could have been detected. However, it is clear that distortion started well within the length that had been destressed and I do not think that the additional destressing, had it been done, would have prevented the track buckling in this case.

21. In conclusion, it is at present impossible fully to explain the buckling of the track in this case. It may remain unresolved, being at best explicable as a chance coming together of a number of factors each working to reduce the margin of safety against lateral distortion. However, the results of tests and investigations still being made may make it possible for a more definite cause to be established. If this is so details will be included in the final Report.

Somerton

22. This accident occurred at 16.31 on Friday, 13th June 1969, the weather again being clear and very warm. The train involved was the 14.45 passenger express from Paignton, comprising a Class 52 "Western" diesel-hydraulic locomotive and nine coaches. Rounding a right hand curve of 60 chains radius in a cutting at a speed of nearly 80 m.p.h. the train ran over a severe distortion in the track and the rear six coaches became derailed.

23. The distortion was seen clearly by both the driver and secondman of the express; both estimated the displacement of the track as between one and two feet, and described the distortion as "S" shaped with the greatest displacement towards the outside of the curve. The driver, on seeing the distortion, made an immediate brake application, but speed was not significantly reduced before the locomotive reached the buckle. The locomotive and the leading three coaches remained on the rails. The fourth coach was derailed all wheels, but remained coupled, and the train divided between the fourth and fifth coaches and between the fifth and sixth coaches. The fifth coach, derailed all wheels, came to rest at an angle across the Up line about 440 yards behind the front portion of the train, and about 100 yards ahead of the remaining four coaches, which were all derailed but remained coupled together.

24. Of the 65 passengers who sustained injury, 53 were taken to Yeovil General Hospital where 11 were detained. The remaining 12 injured passengers continued their journey to Paddington and received treatment at St. Mary's Hospital. One of the passengers in Yeovil Hospital, an elderly gentleman who had sustained slight injury, died on Sunday, 15th June, but I understand that the Coroner attributed death to a pre-existing severe chest condition and said that death was not accelerated by the accident.

25. The emergency services were alerted by a "999" call from a member of the public at 16.36 and the first ambulance arrived on site at 16.47. A total of 8 ambulances and a coach from Wykes Coach Services, Sherborne, attended. The Police and Fire Services were also quickly at the scene and assisted with the entraining of passengers who were continuing their journey. Protection of the lines was carried out promptly by the train crew, and the signalman at Castle Cary took appropriate action when informed of the accident at 16.39.

26. The accident took place on the Main line from the West of England to Paddington via Westbury (Wilts). After passing Somerton station in the Up direction the line starts a long right hand curve of 60 chains radius and is subject to an 80 m.p.h. speed restriction. Approaching the point of derailment it runs through a series of cuttings which are generally WNW to ESE in direction. The gradient is rising at 1 in 264. Drawing 2 at the end of this report shows the general layout and important features.

27. The distortion occurred close to the junction between continuous welded rail track laid in 1962 and new CWR track laid in November 1968. The 1962 track was formed of 110A flat bottom rail on F19 concrete sleepers with SHC fastenings. The 1968 track comprised similar rail on F23 concrete sleepers with Pandrol fastenings. Ballast on both sections was 2½ in. to 1 in. granite. It was generally of full profile, although it is just possible that some deficiency existed in the shoulder ballast on the outside of the curve. The ballast depth below the underside of the sleepers on the outside of the curve was of the order of 2 feet.

28. The 1962 section of track, on which the derailment occured at 124 miles 235 yards, had been laid between 123 miles 418 yards and 124 miles 420 yards on two consecutive Sundays in July 1962 and had been fastened down when the air temperature was between 65°F and 68°F. There was an adjustment switch at a reversal in curvature (123 miles 1,559 yards) and another one at the junction with jointed track (124 miles 420 yards).

29. In March 1968 cant on the curve between 123 miles 1,672 yards and 125 miles 330 yards was increased from 4½ ins to 5¾ ins using 2 tampers and 1 liner. This was done to improve high speed running through the curve: the permanent speed restriction of 80 m.p.h. which had existed prior to the increase in cant remained unchanged.

30. On 17th November 1968 an underbridge at 124 miles 478 yards was reconstructed and this involved a track lift on the Up line of 7½ ins at the bridge. The lift was progressively run out in the Up direction to zero at 124 miles 308 yards, i.e. 112 yards into the 1962 section of CWR. The lift was carried out manually, with jacks to raise the track, and hand packing. After the full lift had been achieved the line was machine tamped. At the time of lifting the air temperature was about 45°F. Rail temperatures were not recorded.

31. On the same day, 17th November, the old jointed track between 124 miles 616 yards and 125 miles 242 yards was replaced by concrete sleepered track in 60 ft lengths, and that between 124 miles 420 yards and 124 miles 616 yards was similarly replaced on 19th November. The following Sunday, 24th November, the 60 ft long service rails were replaced by continuous welded rail and the adjustment switch at 124 miles 420 yards was removed. The air temperature at the time of rail changing varied between 44° and 55° and it was therefore necessary to extend the rail. This was done with rail warmers, one pass being made, starting at the Somerton end of the renewal and finishing at 124 miles 308 yards, i.e. the point where the track lift had terminated. The track was warmed to produce stress free conditions at 75°F and was fastened down as the rail warmer passed. On completion of the warming the gap between the new CWR and the 1962 length was closed with thermit welds. The method of carrying out this warming was not in accordance

with the provisions of Handbook No. 11 which requires warming to start at the free end (which in this case would have been the end farthest from Somerton), to proceed at about 40 feet per minute to the fixed end, and then to return to the free end.

32. On 5th February 1969 a part of the track that had been relayed in November was machine tamped. The Up line between Somerton and Castle Cary was examined with a Matisa Recording Trolley on 11th March 1969 and the record showed the track to have been of a high standard at that time.

33. During the five days preceding the accident the shade air temperature at 16·45 recorded daily at Yeovilton, some five miles from Somerton, averaged 24·1°C (75°F) with a wind force of 10 to 24 knots from a generally ENE direction. On 13th June the temperature at 16.45 hours was 25·4°C (78°F) with a wind force of 2 knots blowing from the south. Rail temperatures were not taken, but from comparisons made with similar situations and weather conditions it is estimated that rail temperatures near the point of derailment were at least 110°F. At the time of the accident the sun was at an angle of 40° to the direction of the railway at the point of derailment, and at an elevation of 41°. See para. 20(f) for remarks on the significance of these angles.

34. On the day of the accident the Leading Trackman responsible for patrolling the line between Somerton and Castle Cary started his inspection of the Down line at 07.30 and passed the 124 mile post at about 09.45, walking towards Castle Cary. He later returned along the Up line, again passing the 124 mile post at about 12.10. Both tracks were in good condition and he saw nothing unusual. Because the day was unusually hot he made a further inspection (as required by instructions issued to him) at about 15.40. This was at 125 miles 1,650 yards where welded point and crossing work connected with ordinary jointed tracks. It was a place that required extra surveillance in abnormal weather conditions and his instructions required him to re-inspect those places on his length that were particularly vulnerable to extreme heat or cold.

35. The last train to pass over the Up line between Somerton and Castle Cary before the accident was the 11.25 Penzance to Paddington passenger train. This comprised a Class 52 "Western" diesel-hydraulic locomotive and nine coaches, the latter all mounted on either Commonwealth or B4 bogies. It passed the point where the buckle later developed at about 15.25. Neither the driver, who had driven over this line regularly during the previous five or six years, nor the guard, who was in the middle of the train at the time, saw or felt anything unusual as they negotiated the Somerton curves.

36. The distortion of the CWR track that caused the accident thus developed after the passage of the Penzance to Paddington train at 15.25 and before the arrival of the Paignton–Paddington train at 16.31.

37. In seeking to establish the reason for the track buckling attention must concentrate on the work that took place in November 1968. After the laying of the new track in that month it is evident that the line was maintained to a high standard and appeared to be in every way up to the specification laid down for a main line. The possibility mentioned earlier that the shoulder ballast may have been deficient is based on opinion rather than measurement, since the profile that existed before the accident was lost during the derailment, but I am satisfied that substantially the shoulder width was the 12 ins called for at that time. However, if the shoulder was at all deficient this would have reduced the safety margin.

38. There is a standard procedure laid down for joining new CWR track onto an old length. In this due emphasis is placed on the importance of ensuring that stress conditions in the old length are not disturbed by the new work, and provision is made for destressing 300 feet into the old length for this purpose. In the particular case at Somerton the standard operation was complicated by the bridge reconstruction nearby and the associated lifting of the track. The fact that the lift continued into the old (1962) length of CWR track before it ran out to zero undoubtedly allowed the end of this length to develop a stress-free condition different from that at which it had been fastened down, i.e. at 65–68°F. Rail temperature at the time of track lifting was 45°F or lower.

39. In the event destressing was carried out at least 336 feet beyond the termination of the new work, and actually up to the point at which the lift had run out. It thus appeared to meet the requirements, and indeed to have exceeded them, but hindsight shows that, in this particular case, destressing should have continued a further distance into the old length. The situation which resulted was that in the new length the track was stress-free at 75°F, well into the old length the stress-free temperature was between 65° and 68°F, but near the junction of the two there was a short length where the stress-free temperature could have been as low as 45°F. Graphs plotted in the course of the investigation showed the probable variations in stress-free temperatures, and the point where the minimum occurred coincided with the point at which the track buckled. Calculations also showed that, with the track stress-free between 65°F and 75°F there would be an adequate safety margin with rail temperature at 110°F, but that the safety margin would be drastically reduced with stress-free temperatures as low as 45°F.

40. On 27th June 1969 the Chief Civil Engineer, Western Region, issued special written instructions that whenever CWR track is disturbed, by lifting, slewing, or track renewals, destressing must be carried out a minimum of 300 feet beyond the limit of disturbance, and that when the ambient temperature is below 50°F the length to be so destressed is to be doubled.

Sandy

41. At 17.37 on Wednesday, 23rd July, the 17.00 King's Cross to Newcastle express passenger train (the Tees–Tyne Pullman) was derailed on buckled continuous welded rail track near Sandy station. The train comprised eleven vacuum braked coaches hauled by a Class 55 "Deltic" diesel electric locomotive.

42. As at Somerton, the distortion in the line was seen by both driver and secondman of the locomotive as they approached. The speed of the train at the time was between 92 and 94 m.p.h. The driver thought the lateral displacement of the track was about 18 ins., and described the whole track as having veered to the left. The main distortion was followed by several other bends of lesser degree. The driver made an immediate brake application and the locomotive and first coach negotiated the buckle and remained on the rails. The next two coaches, still coupled to the first vehicle, became derailed all wheels and this portion of the train, having become detached from the remainder of the train, came to a stand just beyond the Sandy Down Fast Home signal. The rear eight coaches were all derailed, with division taking place between the fifth and sixth coaches. The 4th, 5th, 7th, 8th, 9th and 10th coaches remained upright, straddling the Down Slow line, but the 6th (a Pullman First Kitchen Car) and 11th (the guard's brakevan) over-turned onto their sides.

43. Emergency Regulations were carried out promptly and all lines were protected. Fire, Police and Ambulance services were called at 17.39 and commenced to arrive at the site within 8 minutes. Within a few minutes of the accident all passengers had been detrained and eleven were taken to Bedford General Hospital suffering from minor injuries. All but one were discharged after treatment, the remaining passenger being detained until 25th July for observation.

44. Derailment started at 43m 557 yds on the Down Fast line of the East Coast Main Line about 1,500 yds south of Sandy station. The railway at this point runs SSE to NNW and comprises four tracks, these being (reading from west to east), the Down Slow, Down Fast, Up Fast and Up Slow. The Down Fast is on a right hand curve of 140 chains radius at the point of derailment, the end of the transition being 358 ft to the south. The transition length is 305 ft 6 ins. The gradient is 1 in 786, rising. Maximum permitted speed is 100 m.p.h. Drawing 3 at the end of this report shows the general layout.

45. The track was relaid in November 1959 with 109 lb/yd flat bottom continuous welded rail on Jarrah hardwood sleepers with MRC.2/1 baseplates, Mills C.1 clips and 3/16 in. thick cork-rubber pads beneath the rails. The ballast was slag in reasonably clean condition with depth and profile according to specification. Sleeper spacing was 26 ins centre to centre, i.e. standard for timber sleepered track.

46. Maintenance of the line by on-track machines and mobile gangs was commenced in June 1966, and since then routine correction of line and level has been by mechanical tamping and lining machines. Tamping was carried out in 1967 and again (with lining) in March 1969. On the former occasion the cant was increased from 1½ ins to 2 ins and new cork-rubber pads were fitted. In May 1969 additional ballast was run out to ensure a full ballast profile before the warm weather. After the tamping and lining work in March 1969 no further maintenance was carried out until the accident occurred. A Matisa track record taken on 19th June 1969 showed the track to be well up to the standard required for the permitted speed.

47. During 1968, one baseplate in three on each rail was replaced by a MRC.2/3 type with Mills C.3 clips and new pads. This was done because deterioration of the Mills C.1 clips, due to wear, had been noted. Further changing of baseplates and clips was due to be carried out later in 1969. The baseplates in the area where distortion eventually occurred were changed in September 1968, one sleeper at a time being treated. Soon after the accident a panel of the original track was sent to the British Railways Technical Centre at Derby for testing. These tests showed that the MRC.2/1 plates and C.1 clips, although displaying some expected loss of torsional rigidity, were still of acceptable standard. Further tests of individual sleepers with different baseplates, clips and pads are being carried out but results are not yet available.

48. Between 1966 and the time of the accident a number of short lengths had been welded in to both six-foot and cess side rails as replacements for wheelburned rails or defective welds. As each of these involved destressing the track I have tabulated details as follows:—

Date	Rail	Position in relation to point of derailment	Length of Track destressed	Method of destressing
During 1966	Six-foot and cess	112 ft South	300 ft to each side	Rail warmers
28 February 1967	Cess only	704 ft South	300 ft to each side	,, ,,
9 March 1969	Six-foot only	180 ft North	300 ft to each side	,, ,,

49. I am assured that on each of these occasions the destressing was supervised by a Technical Assistant and that the rails were correctly fastened down within the prescribed stress-free temperature range. The length destressed was as prescribed and should have been quite sufficient to prevent alteration of equivalent stress-free temperatures in adjacent lengths.

50. The section of line concerned was patrolled by a Leading Trackman on Mondays, Wednesdays and Fridays of each week. On the day of the accident (a Wednesday) the Trackman walked from Sandy southwards, starting at 07.30, and returned to Sandy at 16.15, having passed the site of the derailment at about 15.30. He had found nothing untoward during his inspection. Whilst this patrolling was in progress, the Permanent Way Inspector responsible for the line between Cadwell (34½ mile post) and Stukely (62½ mile post) was in the Sandy/Biggleswade area, together with the Track Chargeman from the Sandy Mobile Gang. They had both checked rail temperatures throughout the day and found them to be high in the early afternoon. In the cutting near Biggleswade 100°F was recorded at about 14.00, and 109°F at 17.40 with a maximum of 116°F. Special hot weather patrolling was instituted at 14.00. At about 15.30 the Track Chargeman, having sent members of his gang to points which required special attention, went to the cutting north of Sandy where he found rail temperature to be 119°F. At 16.30 he walked south to the area of Sandy station and recorded 106°F. Since the line was more open south of Sandy, and he knew the length had just been patrolled, he returned to the cutting, where rail temperatures were still very high.

51. At the time of the accident the sun was at an angle of 74° to the direction of the railway at the point of derailment, and at an elevation of 31°. See remarks in paragraph 20(f) for the significance of these angles.

52. The last two trains to pass over the Down Fast line before the accident were the 16.20 King's Cross to York passenger train, which passed through Sandy at approximately 17.00, and the 16.30 King's Cross to Cleethorpes passenger train, which passed Sandy at about 17.06. Both trains were hauled by Class 47 diesel electric locomotives. The 16.20 train consisted of eleven vehicles, nine on B.4 and two on Commonwealth bogies. All vehicles were approved for 100 m.p.h. running and when examined soon after the accident to the Tees–Tyne Pullman were found to be in good mechanical condition. The 16.30 train consisted of eight vehicles of which two were on Commonwealth bogies, one on B.4, four on B.R. 8 ft 6 in. Light Double Bolster bogies and one on ex L.N.E. 8 ft 6 in. Heavy Metro Double Bolster bogies. The speed of this train was limited to 90 m.p.h. At my request a close examination was made of the older stock in this train and tests to establish Ride Index values were carried out at speeds of between 75 and 90 m.p.h. on the East Coast Main line. Results were within acceptable limits, although the ride of one or two of the vehicles was not smooth.

53. Travelling on the 16.20 King's Cross to York train were four railway employees, including a Senior Technical Assistant in the Chief Civil Engineer's department. They were together in a compartment located over the leading bogie of a coach in the middle of the train. Approaching Sandy, and at a point which the Technical Assistant later estimated to be close to the site of derailment, they felt a noticeable, but not violent, jolt with the coach moving sharply to one side and back again. However, the train crew had not noticed any unusual riding, nor anything wrong with the track. The train speed approaching Sandy was between 80 and 85 m.p.h.

54. Neither the driver nor the guard of the 16.30 London to Cleethorpes train, which approached Sandy at between 75 and 80 m.p.h., noticed anything wrong with the track or the riding of the train. The guard was in the centre of the train at the time, and confirmed that no passenger had complained of rough riding.

55. Soon after the accident, the Chief Civil Engineer, Eastern Region, carried out a detailed examination of the track leading up to the point of derailment. This showed the transition and the start of the circular curve to be well within permissible tolerances for gauge, line and level. Voids along the whole length were negligible. The survey brought to light, however, one unusual feature. Side cutting on the high rail increased uniformly throughout the transition and the beginning of the circular curve to a maximum of 26° at ¾ in. below rail head: this amount of sidecut then remained constant throughout the curve except for a length of approximately 23 ft, where the cut suddenly became significantly deeper (1 in.) and of a somewhat different form (23° with a slight "lip" of metal at the lower part of the sidecut). The initial point of derailment was in the centre of this 23 ft length. Rail sections showing the two patterns of sidecutting are shown in Drawing 4.

56. In addition to the survey, a test was made to determine the actual stress-free temperature on the straight track up to the start of the transition. It would have been valuable to have had these tests on the curve, but the relaying made necessary by the derailment had altered the characteristics of the track in those areas where tests would have been most useful. The results of these tests carried out over a 900 ft length of the straight gave an average stress-free temperature of 73°F, thus showing that there had been no significant lowering of the stress-free temperature over this length.

57. As with Lichfield, there is no immediately obvious reason for the buckling of the track. The line was maintained to a high standard, and was apparently in all respects within the specification current at the

time, a specification which, theoretically, should have ensured an adequate factor of safety against lateral distortion. One is forced, therefore, to look at unusual or distinctive features, and there are four of these. Taking them in turn:

(*a*) *The baseplates and clips.* One in three had been changed because of deterioration and this must be regarded as a possible weakness in the track in view of the importance of strong fastenings both as a factor in the lateral stiffness of the track and as a restraint against longitudinal creep. However, the tests made so far at Derby do not show any dramatic lowering of the fastening strength and certainly nothing sufficient to cause buckling.

(*b*) *Destressing operations.* There had been three occasions since 1966 when destressing was necessary on the Down Fast line in the area. Two of these destressings had included the length where the distortion eventually took place. There is, however, no evidence to show that these operations were carried out other than correctly and the results of the tests mentioned in para. 56 above indicate that the track involved in the 1967 destressing (the one that did not affect the length where derailment occurred) had been done properly since the track was found to be near its designed stress-free temperature. Another factor to be considered is that in February 1967 and March 1969 only one rail was destressed. Although this was not forbidden in instructions then current it is possibly a questionable practice, first because of the racking effect when only one rail is relieved of stress, and secondly because it leads to the possibility of the rails not being stress-free thereafter at identical temperatures.

(*c*) *Sidecutting of the high rail.* The unusual sidecutting described in para. 55 developed prior to March 1969. It was noticed before then, and special attention was given to the area when the track was tamped and lined in March. Since the lining a watch was kept to see if the sidecutting continued and apparently it did not, since grease from a curve oiler was seen to build up on the inner face of the rail. However, it is clear that at some stage the flanges of vehicles had been riding hard against the high (i.e. outer) rail of the curve over a short distance at this point. The reasons for this are not clear: it could have been the result of some pitch or roll of locomotives or rolling stock entering the curve at consistently high speeds, but it is more likely to have been caused by some small misalignment in the track at that point.

(*d*) *The 16.20 train.* There is little doubt that something was wrong with the track south of Sandy at about 17.00 on the day of the accident. The Technical Assistant who noticed a jolt at this point had travelled the line regularly since 1965 and was used to assessing the riding almost as a matter of course. The sudden lurch was the subject of comment at the time in the carriage and thus cannot be explained as a subjective recollection after the railway staff concerned had learned of the accident. It is hard to explain why nothing was seen or felt by those in the 16.30 train which passed over the same length of track six minutes later, but a small distortion might well have passed unnoticed by a locomotive crew. I think that some distortion of the line had started by 17.00 and that an incipient buckle might well have been further aggravated by the passage of the two trains preceding the Tees-Tyne Pullman, at a time when rail temperatures were at or near the maximum.

58. Although again no firm conclusion can be reached on the reasons for the track buckling at this point, I feel that it is not a coincidence that derailment should have occurred at precisely the position where an unusual pattern of sidecutting had developed in the past. The track at this point must have been subject at some stage to a lateral thrust concentrated over a short distance as wheel flanges rode hard against the outer rail of the curve, and this must have resulted in some tendency for the track to move outwards. It is clear that the track, after lining in March, was aligned correctly, but if some weakness existed in the track, some tendency to move back into its old position, this could well have reached a critical condition when the track was subject to high compressive forces. Other factors, not in themselves remarkable, might have combined to reduce the temperature at which this critical condition was reached. Thus the fact that some slight weakness existed in the fastenings would have contributed. It is hard to quantify these factors, but some idea of the margin required is shown by the fact that experiments carried out before 1961 on new, straight track, similar to that at Sandy, showed such track to be capable of withstanding a compressive force of up to 168 tons without buckling. This figure would be reduced slightly for track curved at 140 chains radius, and for worn fastenings. Taking the stress-free temperature at Sandy to have been 73°F, and maximum rail temperature to have been as high as 120°F, this gives a total force in the track of just over 84 tons. There should thus have been a safety factor of over 1·5, even allowing for the curve and wear factors, but since the track nevertheless failed I can only attribute it at this stage to an inherent weakness in the track at this precise point.

GENERAL CONCLUSIONS ON THE DISTORTIONS THAT OCCURRED IN 1969

59. There can be no doubt that some factor in the meteorological conditions over central England during June and July 1969 searched out an unsuspected weakness in the continuous welded rail track as laid on British Railways. Examination of these climatic factors is continuing but it is already clear that it is not maximum ambient temperature alone, nor total hours of sunshine that are significant. Much more significant appears to be the range of temperature between early morning and mid afternoon, and the repetition of these quite large temperature cycles from day to day.

60. 90 per cent of the distortions could be attributed to one of the following:

(*a*) Failure to comply with the instructions for laying or maintaining CWR track.

(*b*) Recent interference with the consolidation of the ballast.

(*c*) The effect of discontinuities in the CWR track, such as catchpoints, switches and crossings, or insulated joints.

(*d*) Extraneous factors, such as formation subsidence.

All these are matters which are within the provenance of the Civil Engineering Department to improve, and the situation emphasises the need for special measures at points of weakness in the CWR track system as well as a more specific link between maintenance work and weather conditions. Nevertheless, the remaining cases for which no obvious cause can be found, and the marginal nature of many of the deviations from the standards laid down, suggest strongly that either the factor of safety against buckling in the current design is not sufficient, thus allowing a statistically significant number of buckles to occur, or that there is some other undetermined factor causing the loss in stability. The programme of research now under way at Derby and described later in the report is directed to evaluating those two aspects of the problem.

61. One point worth mentioning at this stage is the obvious value of the present arrangements for extra patrolling in abnormal weather conditions. The fact that all but three of the serious distortions were discovered before trains passed over them speaks for itself. It may be that such patrolling will have to be still further increased in future, even if the level of distortions is brought back to its pre-1969 figures.

MEASURES ALREADY TAKEN BY THE BRITISH RAILWAYS BOARD

62. Certain measures put in hand following the two derailments of freightliner trains on buckled CWR track during 1968 have already been described in Colonel Reed's Report on his Inquiry into these two accidents. In brief, these measures were:

(*a*) A programme of investigation in Scottish Region to determine the actual stress-free temperature of existing lengths of track.

(*b*) A series of tests to investigate the riding characteristics of freightliner vehicles.

63. The tests in Scottish Region have now been finished, and have confirmed a general lowering of stress-free temperatures. Of 45 lengths of CWR investigated 28 were found to have a loss of 6°F or more in stress-free temperature. Similar tests carried out on other Regions seem to confirm the pattern found in Scotland.

64. The result of tests carried out on freightliner vehicles was described by Colonel Reed in his Report on the derailments at Berkhamsted and Auchencastle. Since then further tests have been made from which it is concluded that bogies of these wagons when in the unloaded condition do not ride as satisfactorily as does a loaded bogie. There is also further evidence that the degree of rotational stiffness at the bogie pivot is an important feature of design. The requirement is to design a bogie which has a rotational stiffness of a magnitude sufficient to prevent excessive bogie hunting at high speed but at the same time does not prevent the bogie from negotiating curved track with minimum lateral loads at the tyre flanges. There has been evidence on the track to indicate that side loads have been excessive on freightliner wagons involved in the derailments mentioned in the present report. This aspect of design is being further pursued with the expectation that acceptable ride performance will be achieved with the existing wagons over track maintained to normal standards. Other tests with freightliner wagons operating at low speed through curves and crossovers have confirmed the need to restrict the present design of bogie in its degree of lozenging or crabbing. A modification to restrict clearances between bogie bolster and side frames has been shown to achieve this and BR plan to modify all existing wagons accordingly.

65. Since June/July 1969 the British Railways Board have taken the following action to deal with the present situation:

(*a*) *Investigation.* A special three-man committee was set up in August 1969, under the Chief Civil Engineer, BRB, to examine in detail all cases of track buckling on CWR lines during 1969. The members include a representative from the British Railways Research Centre at Derby. I have been associated with the work of this committee and have been kept informed of the progress of the investigation. The work of analysis is still continuing.

(*b*) *Ballasting Programme.* Until the summer of 1969 the standard ballast shoulder for CWR track was set at 12 ins for straight track and 15 ins for curved. It was obvious that in some cases ballast was barely up to these minimum requirements. On 29th July 1969 the Chief Civil Engineer, BRB, ordered the width of shoulder to be increased to the following dimensions:

(i) Straight track—15 ins.
(ii) Curved track, radius more than 40 chains—18 ins minimum.
(iii) Curved track, radius less than 40 chains—21–24 ins.

In addition, ballast is to be heaped to the maximum extent on the shoulder and the four-foot and six-foot ways are to be fully filled up. Weak points, such as insulated joints or catch points on the straight, are to be treated as for curved track, and such places on curved track are to be given correspondingly extra ballast. This programme calls for a massive effort by both the Civil Engineering and Operating Departments, but I am glad to say that at present all Regions report that the programme is up to schedule, and the British Railways Board are confident that all the additional ballast will be in position before the onset of the warm weather in 1970. Obviously, this special programme (and the further measures reported below) will mean a slowing down of the current and planned track renewal programme, especially that for the first half of 1970, but this programme is being studied carefully, so that safety is not endangered by deferring renewals that are themselves essential from a safety aspect.

(*c*) *Destressing existing track.* Also on 29th July, the Board's Chief Civil Engineer ordered a special exercise in all Regions to destress existing lengths of CWR track in order to ensure that the stress-free temperatures are correct before the summer of 1970. This again is a very large scale operation, and it is clear that the whole existing 4,600 track miles cannot be destressed in the time available. Priority is therefore being given to lengths which Regional Chief Civil Engineers consider possibly suspect. The programme will continue into and beyond the summer of 1970, but by the onset of this summer most if not all of the potentially suspect lengths will have received attention. When this destressing is carried out, opportunity will be taken to check the existing stress-free temperature, and this should provide valuable information to add to that already obtained from the tests conducted in Scottish Region (See para. 63).

(*d*) *Revision of Code of Practice.* A new interim Code of Practice for laying and maintaining CWR track has been issued to Regional Chief Civil Engineers. Prior to this a number of special directives had been issued. The new Code of Practice supersedes Civil Engineering Handbook No. 11 (see para. 5) which will be re-published in due course. The new edition will incorporate the amendments contained in the interim Code. The main changes covered by the new code are as follows:—

(i) As far as practicable track maintenance work on the high speed and heavily trafficked lines is to be planned for September to April inclusive.

(ii) The stress-free temperature range at which CWR track is to be fastened down is now 75–80°F with 80°F being the aim in every case. (The previous range was 65–75°F, narrowed to 70–75°F by a special instruction issued during August 1969). The risk of damage to the track by large tensile forces during very cold weather is not now thought to be great.

(iii) The method of obtaining rail temperatures before the start of stressing operations has been improved. Magnetic contact rail thermometers are to be kept centralised in Divisions or Districts, so that any errors in reading between one instrument and another can be detected, and they are to be checked for accuracy with special electric temperature meters purchased for this purpose.

(iv) The level of technical supervision required when stressing operations are carried out has been raised.

(v) Instructions are included which make it necessary to destress both rails in a track whenever destressing is done.

(vi) Further limitations on the work which can be carried out on the track when rail temperatures (or forecast rail temperatures) exceed 90°F have been imposed, and special arrangements have been made for cases where work has been carried out and the rail temperature rises to above 90°F during a five day period following the completion of the work.

(vii) Additional precautions are to be taken to strengthen points of discontinuity in the CWR track.

(*e*) Following consultation with the Meteorological Office, British Railways Board have arranged to receive, from 1st April to 30th September, a daily forecast of weather conditions for the following three days. These forecasts are expected to give a reliability as far as temperature is concerned of within 3°F for the first day, with a possible error of up to 7°F for the third day. In addition to temperature forecasts, direction and speed of wind will be predicted, together with cloud cover. These forecasts will be relayed to Civil Engineering offices in all Regions and will form the basis on which plans will be made for work carried out on the track, and for the implementation of special measures. Available records giving the highest observed excess of rail temperature over air temperature will enable the forecast air temperatures to be converted into maximum expected rail temperatures.

(*f*) To improve the standard of operator efficiency in destressing operations the British Railways Civil Engineering Training School at Watford has arranged a special series of one-day courses on destressing, and these are being attended by permanent way staff from all Regions. It is intended that 300 students shall have attended before next summer.

(*g*) The standard F23 concrete sleeper has been redesigned to give a larger end area to bear against the shoulder ballast. In addition, for all future new work or track renewals involving CWR on main lines the standard concrete sleeper spacing is to be reduced to give 26 sleepers per 60 ft length on straight track and 28 per length on curved track. This compares with 24 and 26 per length respectively at present. With the reduction in spacing the redesigned sleeper will have fewer pretensioning wires and hence a reduced moment of resistance, but the total weight will be slightly increased, and the resistance of the track system as a whole to lateral distortion will of course be considerably increased.

(*h*) The Board authorised the purchase of twenty on-track crib and shoulder consolidating machines early in 1969 and the first should be delivered in May 1970. In the meantime experiments are being made with modified Kango hammers (a flat steel plate attached to the end) for compaction of both the shoulder and crib ballast. The Board has also given the manufacturers of tamping and lining machines a requirement for a new machine which will incorporate a ballast shoulder and crib consolidation capability in addition to tamping and lining. It is believed that British Railways are the first to give a firm requirement for such a machine.

(*i*) The supply of 125 new 50-ton ballast wagons for the Chief Civil Engineer's Department was agreed by the British Railways Board Investment Committee in mid-November 1969, and this expenditure was quickly approved by the Minister. The first wagons should be available by September or October 1970, and the whole build completed by the end of 1970. Although these wagons will not be available to help with the present ballasting programme they will make it easier for Civil Engineers to provide the requisite ballast when track is relayed or maintained in the future.

RESEARCH AND FUTURE WORK

66. In addition to the measures outlined in para. 65 above, the Board have initiated an intensive research and testing programme with the aim of finding quick and positive answers to the two main problems stated in para. 60 above, viz, the apparent insufficiency of the factor of safety in the current design and the presence or otherwise of some other factor tending to cause a reduction of stability with time. The programme is being conducted partly by the Chief Civil Engineer, BRB, and partly by the Director of Engineering Research at the B.R. Research Department at Derby.

67. The main headings under which this work is proceeding are as follows:

(*a*) *Temperature.* Tests to determine the relationship between ambient temperature, rail temperature as measured by field equipment in current use, and actual internal rail temperatures as measured in the laboratory.

(*b*) *Cold rolling of rails.* Tests to determine whether a cold rolling effect is responsible for the observed lowering of stress-free temperatures, and if so the extent of such effects and whether they are of a "once and for all" nature, or a continuing one.

(*c*) *Stress-free conditions.* Tests to investigate the frictional losses associated with rail stressing, and also the degree to which rails are in fact "stress-free" when they are fastened down.

(*d*) *Fastening resistance.* Tests to bring up to date the available information on toe-loads exerted by different designs of fastening with differing degrees of wear.

(*e*) *Ballast Resistance.* These tests, which are of fundamental importance, will investigate further the contribution of the ballast to stability, and seek to determine the optimum economic method of increasing the lateral resistance so that it becomes substantially above the present value. The trials will include sleeper friction on base, sides, and ends as affected by variations of sleeper surface and ballast compaction, dynamic considerations (including the precessional wave effect and simulation of the varying dynamic loads of vehicles passing over the track), and a study of the effect of "thermal cycling" on the lateral displacement of the sleepers.

68. The time scale for these experiments varies with the complexity of the problem. Answers to (*a*), (*b*), (*c*), and (*d*) should be available by mid 1970: the work involved in (*e*) will take considerably longer, possibly as much as two years.

COMPARISON WITH CONTINENTAL DESIGN AND PRACTICE

69. The German Federal Railway (DB) possess at the moment over 27,000 miles of welded rail track, and the French National Railways (SNCF) about 7,000 miles. Not all this is continuously welded, the DB

having a considerable mileage of track formed of welded rails jointed at intervals of less than 200 metres. This length is the minimum required for full restraint in the centre of a rail length, and hence the minimum for a truly "continuous" welded rail. Both administrations have experienced buckling on continuous welded track and on the shorter welded lengths, and both have assisted us and the British Railways Board with exchanges of information on common problems.

70. The design of track on the Continent is not basically different from that on British Railways. Generally, the DB has placed emphasis on achieving lateral stiffness by means of very strong fastenings beween rails and sleepers, whilst the SNCF has concentrated on increasing the lateral resistance in the ballast, mostly by means of the two-block concrete system instead of monolithic sleepers. Other continental railways tend to follow either French or German practice, with some variation for local conditions. Main design features on French and German Railways are:

(*a*) *Rails*. The DB uses a rail of 49 kg/m and the SNCF has standard sections of 46 and 50 kg/m. Both administrations use heavier sections of 60 kg/m for lines carrying exceptional axle-loads or traffic densities. The standard British Railways 113 lb/yd rail weighs just over 56 kg/m. It must be remembered that a heavier rail, whilst offering more stiffness, will develop a correspondingly greater compressive load for a given rise in temperature.

(*b*) *Sleepers*. Wood, concrete and steel sleepers are all used for CWR track. Dimensions are generally somewhat smaller than British Railways equivalents, but the number of sleepers in a given length is greater. DB uses steel plates on the end or sides of wood sleepers as a means of increasing ballast resistance. The steel sleeper, by virtue of its hollow underside and sloping ends has a very high resistance to lateral movement.

(*c*) *Fastenings*. Many designs of fastening are used, most being comparable from a strength point of view with British Railways designs, although the standard DB fastening is exceptionally strong and rigid.

(*d*) *Ballast*. Profiles are not dissimilar in the three countries. DB uses mechanical means to consolidate the ballast shoulder on curves and other selected places.

71. Laying methods are also similar, each administration welding standard rails into long lengths under factory conditions and then welding these on site. DB specifies a minimum length for site installation of 120 metres, and a maximum of 360 metres. British Railways rails are welded into lengths varying between 150 and 400 metres before installation. French and German railways usually lay the welded rails directly, whilst British Railways, because of the severely limited periods of track occupation available, renews track first with standard 60 ft rails (in prefabricated lengths) and then re-rails, usually on a following weekend, with the long rails.

72. The expected range of rail temperature and the stress-free temperature at which rails are to be fastened down are specified by the three administrations as follows:

	Temperatures °C (°F in brackets)			
	Estimated Rail Temperatures			Stress free temperature at which rails are fastened down
	Maximum	Minimum	Range	
BR	53·3 (128)	−13·3 (8)	66·6 (120)	24·0 to 26·6 (75 to 80)
DB	60·0 (140)	−30·0 (−22)	90·0 (167)	Mean of highest and lowest rail temperatures for the Region concerned plus or minus 5°C with fastening down at the higher value whenever possible. In practice this means fastening down at between 17·0 and 23·0 (63 and 74).
SNCF	60·0 (140)	−20·0 (−4)	80·0 (144)	20·0 to 32·0 (68 to 90)

73. Maintenance methods on the three railways are generally similar, with each using mechanical maintenance to an increasing extent. The DB forbids work on the track which in any way disturbs the ballast when rail temperature is more than 15°C above the stress-free temperature. British Railways forbids such work when rail temperature is above 29°C. The SNCF forbids *any* work which disturbs the ballast compaction (except in emergency) between May and September but, of course, they are not restricted on track occupations at other times to the same extent as British Railways. All three administrations specify extra patrolling of CWR track during periods of abnormal weather.

74. Minimum radii for curves are laid down for track with CWR. The British Railways minimum is 600m, DB permits 500m with wood sleepers and 400m with concrete sleepers, and SNCF a minimum of 500m.

75. No comparison is made at this stage with practice in America and other non-European countries because environmental and traffic conditions are generally very different from those in the United Kingdom. However, information is being collected on differences in design and practice, and any worthwhile comparisons will be made in the final Report.

INTERIM CONCLUSIONS AND REMARKS

76. British Railways adopted continuous welded rail track as a standard in 1959 following lengthy technical investigations, and at a time when such track was already in use on many other Railways. The form of track adopted was necessarily designed for the national temperature range and the humid and generally corrosive atmosphere. The advantages to be gained from the use of CWR made its adoption almost inevitable once its practicability was established. Apart from the more comfortable ride for passengers these advantages included economic ones, such as an extension of rail life by between 30 per cent and 40 per cent, savings in the cost of track maintenance, extended sleeper life, and reduction in fuel costs and wear and tear on rolling stock, as well as the important gain in safety resulting from the elimination of rail joints. The latter have always been the weakest point in conventional jointed track and by far the greatest number of rail breaks, and those potentially the most dangerous, have been associated with the fishbolt holes at rail ends. It will be recalled that the derailment of a passenger train at Hither Green (Southern Region) in November 1967, in which 49 people were killed, resulted from a rail break at a joint in conventional jointed track.

77. Experience between 1959 and 1968, during which period the mileage of CWR track grew from 200 to nearly 4,000 miles, seemed to show that the track design and the specification for laying and maintaining it were sound. The annual rate of distortions was small and constant; many more distortions occurred each year on the old jointed type of track in spite of the provision for heat expansion which this form of track provides. Even the two derailments that occurred on CWR track during 1968 could perhaps be regarded as special cases. In each the track buckled actually under the train, in each the train was a freightliner and in each some element of human error was present. However, the events of the summer of 1969 indicated, firstly, that the factor of safety against buckling with the track subject to high thermal compression was insufficient, and secondly that the old rules for the laying and maintenance of the CWR track and the interpretation and application of these to work on the ground left something to be desired.

78. Once these facts came to light it was clear that the first priority had to be to ensure that existing lines laid with CWR would be safe for traffic by the onset of warm weather in 1970. Paragraphs 62 to 65 in this Report detail the steps already taken and being taken by the British Railways Board to this end. I am satisfied that these measures are the best that can be taken in the time (and with the knowledge) available and that the Board's vigorous implementation of the programme to add extra ballast and to destress any suspect lengths of CWR give good grounds for thinking that the number of distortions in 1970 should once again be very small.

79. As to the future, it is obvious that definitive answers must be found to the technical questions posed: why the factor of safety is less than expected, and why the stress-free temperature reduces with time. The programme of research outlined in para. 67 should produce these answers, and I hope that this work will be co-ordinated to mutual advantage with similar work undertaken by other member administrations of the International Union of Railways.

80. The immediate measures to guarantee the safety of the existing CWR track in this country, and the eventual destressing of the entire existing mileage, should prevent further serious trouble on these lines. As to track laid from now on, the measures planned, including the increased number of sleepers in a given length, increased ballast, and redesigned sleepers, will provide a track that it is estimated will have at least a 15 per cent greater resistance to lateral distortion. This, together with the raising of the stress-free temperature, should provide a much increased safety margin. The long term situation must however depend on the outcome of the tests and experiments being carried out at Derby and elsewhere and, since these have a secondary aim (subordinate to the prime requirement of increased safety) of developing track designs and maintenance techniques which are the optimum from an economic point of view, some change in the eventual specification may well become necessary. Progress in this direction and on all the other points which have necessarily been left inconclusive in this Interim Report, will be covered in my final Report.

I have the honour to be,
Sir,
Your Obedient Servant,
C. F. ROSE,
Major.

The Secretary,
Ministry of Transport.

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